



HOW TO SQUAT

**The Definitive Guide
By Greg Nuckols**

Table of Contents

[How to Squat: The Definitive Guide](#)

[Super Basic Physics](#)

[Force](#)

[Moment](#)

[Anatomy](#)

[Spine](#)

[Pelvis](#)

[Femur](#)

[Tibia and Fibula](#)

[Intervertebral Joints](#)

[Hip](#)

[Knee](#)

[Ankle](#)

[Spinal Erectors](#)

[The "Core"](#)

[Gluteus Maximus](#)

[Hamstrings](#)

[Adductor Magnus](#)

[Quadriceps](#)

[Calves](#)

[Biomechanics](#)

[Planes](#)

[Basic Demands in the Squat](#)

[Biarticular Muscles](#)

[Squatting: The Setup](#)

[Bar placement](#)

[Hand position](#)

[Wrist position](#)

[Elbow position](#)

[Walkout](#)

[Stance width](#)

[Foot Angle](#)

[Bracing](#)

[Creating full-body tension](#)

[Setup Checklist:](#)

[The Descent](#)

[Cuing the Descent](#)

[Speed of Descent](#)

[Depth](#)

[The Ascent](#)

[Initiating](#)

The Sticking Point

Diagnosing Weaknesses

- 1) Quads
- 2) Core
- 3) Hips

Common Questions and Issues

- Are squats safe?
- What do I do about buttwink?
- Why do people's squat forms vary so much?
- Can everyone squat ass to grass?
- Should I have a vertical bar path?
- Is a wide stance squat easier?
- Where should I focus my eyes?
- What should I do about elbow pain?
- How should I squat if I want to build my quads?
- Can I stick solely with squats to maximize leg development?
- What should I do about knee or back pain?
- My knees are caving in. Is that bad? If so, how do I fix it?
- The bar is uncomfortable on my shoulders.
- The weight is shifting forward and I'm losing my balance.
- What should I do about tight ankles?
- How do I correct the weight shifting to one side?
- Do I have to squat below parallel?
- Is it okay if my knees go past my toes?
- Will squats make me better at other sports?

Bar Position

- Should you high bar squat, low bar squat, or front squat?

Equipment

Bullet Points

Sources

Most people should squat. Do you want bigger legs? You'd be hard-pressed to find a better exercise than the squat. Do you want to become more athletic while decreasing your injury risk on the field or the court? Squats should probably be at the core of your training program.

And of course, do you want to get stronger? If so, there are few exercises that can build or test head-to-toe strength as well as the squat (I'd put deadlifts on the same level, with push press close behind).

Of course, I probably don't need to tell you any of that. If you sought out or happened upon this guide, you probably already know that the squat is pretty awesome. You're primarily interested in improving your squat, squatting heavier weights, or building a set of legs that would get a nod of affirmation from Tom Platz.

If so, you're in luck.

Squats come in all shapes and sizes, and can be used for a variety of training goals. This guide is going to break down the movement in-depth, teach you how to optimize your squat technique, and teach you how to start maximizing your squat training.

If you're new here, you may be asking yourself, "who is this guy, and why should I care what he has to say about squatting?"

Fair questions! I'm a coach and drug-free powerlifter. I've been training for 11 years and coaching for 8. I've squatted 650lbs without knee wraps at 220lbs and 750lbs with knee wraps at 242lbs in competition. The 750lb squat was an all-time drug-free world record across all federations. I've coached lifters at all experience levels, teaching hundreds of new lifters how to squat on one end of the spectrum, and training several 600lb squatters and 3x bodyweight squatters on the other end of the spectrum. I've also learned from some of the best squatters in the world like Chad Wesley Smith and Max Aita. This is combined with a thorough understanding of the biomechanics of the lift. Check the reference list at the end of the article; it's tough to make it through that much

scientific literature without picking up a few tidbits along the way (which largely match my personal experiences as an athlete and coach, I'll note).

I don't say any of that to toot my own horn. I just want you to know I'm not just some random internet dude opining about the squat. I'd never claim that everything I say is right just because I squat a lot, and I'm entirely open to changing my views as I gain more experience, talk to more high-level athletes and coaches, and as new scientific evidence is published.

Super Basic Physics

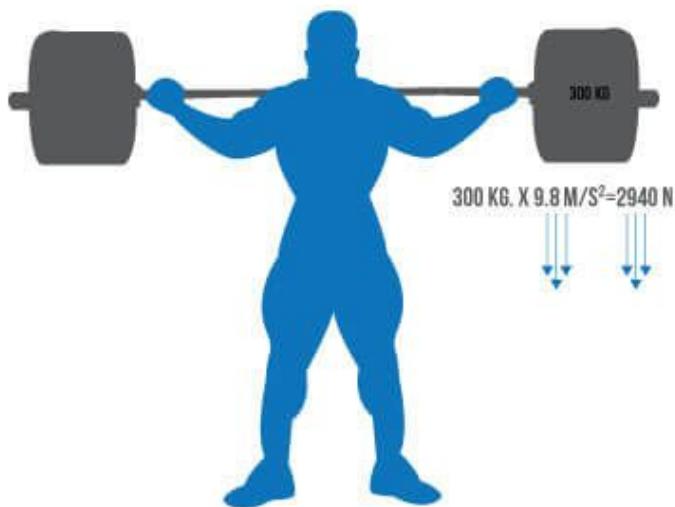
There are a few simple terms we need to understand that describe how our muscles interact with our bones to produce the movements that (hopefully) result in a good-looking squat.

Force

The first is force. Force is the product of mass and acceleration, typically calculated in Newtons (one Newton is the force it takes to accelerate a 1kg mass at a rate of 1m/sec^2). Most important for our purposes here, force is *linear*: it describes things that are being pulled or pushed in a straight line.

So, let's say you have a 300kg bar on your back. The 300kg bar represents the mass component of force. If you weren't supporting the bar, it would accelerate downward at 9.8m/sec^2 (due to gravity), so the bar is exerting $300\text{kg} \times 9.8\text{m/sec}^2 = 2940\text{N}$ of force upon your body. The direction of the force is the direction that gravity is pulling: straight down. Similarly, when our muscles contract, they exert a force pulling one end of the muscle straight toward the other end.

FORCE



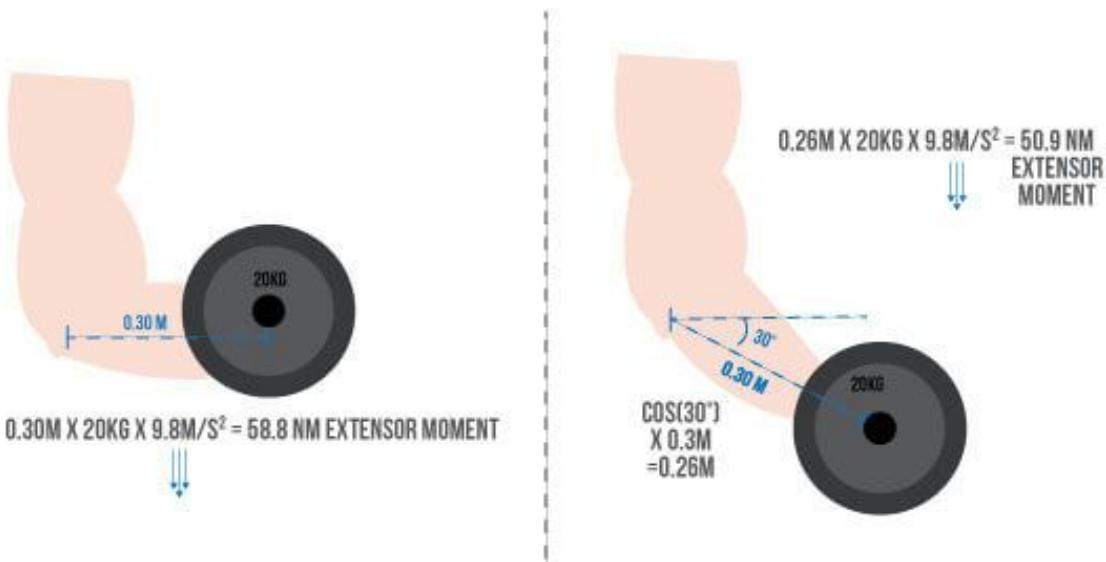
Moment

The second is **moment**. Moment is force applied about an axis, typically calculated in Newton-Meters – the force applied, multiplied by the distance from the axis perpendicular to the direction the force is being applied. While force is linear, moment is rotational.

So, let's say you're curling a 20kg barbell. Your upper arm is straight down by your side, and your forearm, which is 30cm long, is parallel to the floor. You'd calculate the force the barbell is exerting in the same manner as the example above: $20\text{kg} \times 9.8\text{m/sec}^2 = 196\text{N}$ of force, directed straight downward. Then, to calculate the moment the barbell is exerting at the elbow, you'd multiply 196N by the distance between the barbell and your elbow (called the *moment arm*) in meters: $196\text{N} \times 0.30\text{m} = 58.8\text{Nm}$. Since this moment is exerted downward, which would extend the elbow with the forearm in this position, we'd term this an *extensor moment*. If you wanted to continue curling the bar upward, you'd need to produce a *flexor moment* greater than 58.8Nm with your biceps

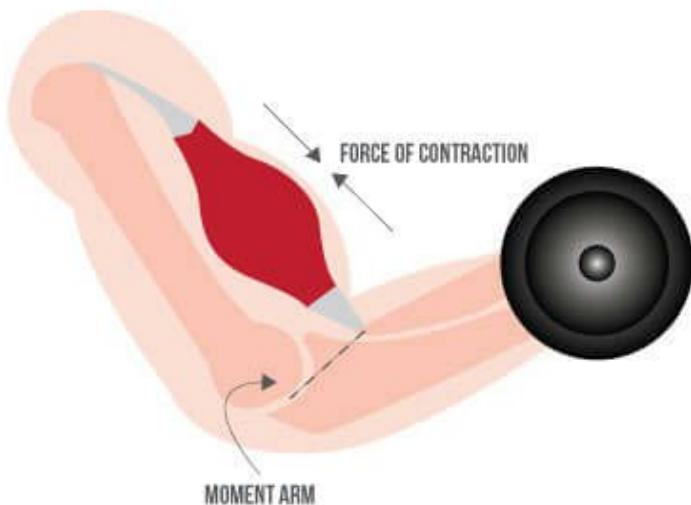
and brachialis. Since the moment arm is the distance between the axis of rotation and the load, measured perpendicularly to the direction the force is being applied, the moment arm would be shorter and the moment would be smaller if the elbows were either a bit more flexed or a bit more extended, even though the forearm would be the same length.

EXTERNAL MOMENT



Moments imposed by a load on your musculoskeletal system are called *external moments*, and moments produced by your muscles pulling against your bones are called *internal moments*. Internal moments are calculated the same way external moments are. The force component is the contractile force of the muscle, and the moment arm is the distance a muscle attaches from the center (axis of rotation) of the joint it's moving. So, for example, if the patellar tendon (which transmits the force of the quadriceps to the tibia) inserts 5cm from the center of the knee joint, and the quads contract hard enough to exert 10,000N of force perpendicular to the tibia, the internal extensor moment would be $10,000N \times 0.05m = 500\text{Nm}$.

INTERNAL MOMENT



$$\text{CONTRACTILE FORCE} \times \text{MUSCLE MOMENT ARM} = \text{INTERNAL FLEXOR MOMENT}$$

To produce movement, your muscles contract. By doing so, they produce a linear **force**, pulling on bones that act as **levers**, producing flexor or extensor **moments** at the joints they cross, with joints acting as the **axes of rotation**. In the case of the squat, you're primarily trying to produce **extensor moments** at the knee and hip that exceed the **flexor moments** at those joints imposed by both the bar and your own bodyweight. If you can do that, you exert a **force** on the bar that exceeds the force the bar is exerting on your body, and *voilà!* A successful squat.

Putting all of this together, there are a few *very* basic principles to take away from this:

1. In the squat, the load (the barbell and your body weight) applies a downward **force** that exerts *external flexor moments* at your knee and hip, and an external dorsiflexion moment at your ankle.

2. The size of the external flexor moment you have to overcome to lift a weight depends on two things: The load itself, and the length of the moment arm. If the load increases and the moment arm stays the same length, if the load stays the same and the moment arm gets longer, or if the load increases *and* the moment arm gets longer, the external flexor moment that your muscles must overcome increases. This is why lifting heavier weights is harder than lifting lighter weights (duh), and why people with longer limbs (and thus longer moment arms at the knee, hip, or both) generally have a tougher time squatting a given load than people with shorter limbs.
3. The two factors that determine whether your muscles can produce large enough *internal extensor moments* to lift a load are the attachment points of the muscles, and the force with which they can contract.
4. Attachment points play a huge role because muscles generally attach very close to the joint they move, so small variations can make a big difference. For example, [this study](#) found that the patellar tendon moment arm varied from 4cm to 6cm. To produce a knee extensor moment of 500Nm like the example above, the quads of someone with a 6cm moment arm would have to contract hard enough to exert 8333N of force perpendicular to the tibia, whereas the quads of someone with a 4cm moment arm would have to contract with 50% more force to produce the exact same knee extensor moment – 12,500N!
5. Unfortunately, you can't change muscle attachment points, so the only factor within your control is increasing contractile force. There are only two ways to do that: a) increase your skill as a squatter so your current muscle mass can produce more force during the movement and b) add more muscle!

Things get just a little more complicated than that, but this should give you a good enough grasp on the terminology we'll be using moving forward. If this is still hazy for

you, you can download a free [physics textbook here](#) (legally) that's actually exceptionally good.

Now, though, it's time to look at the muscles and bones that play the biggest roles in the squat.

Anatomy

The squat is a full-body movement, so there is a multitude of muscles and bones involved; but to simplify things, we really only need to look at four bones or groups of bones, seven muscles or groups of muscles, and four joints or groups of joints. This provides us with the basic understanding of the tissues that are carrying out all that physics stuff in the last section, and provides us with some basic information that will help us discuss the biomechanics of the squat.

Spine



The spine runs from the base of your head to the top of your pelvis and is made up of 24 vertebrae. The vertebrae are split into three general sections: seven cervical vertebrae in your neck, twelve thoracic vertebrae running from the base of your neck to the bottom of your rib cage, and five lumbar vertebrae running from the base of your rib cage to the top of your pelvis.

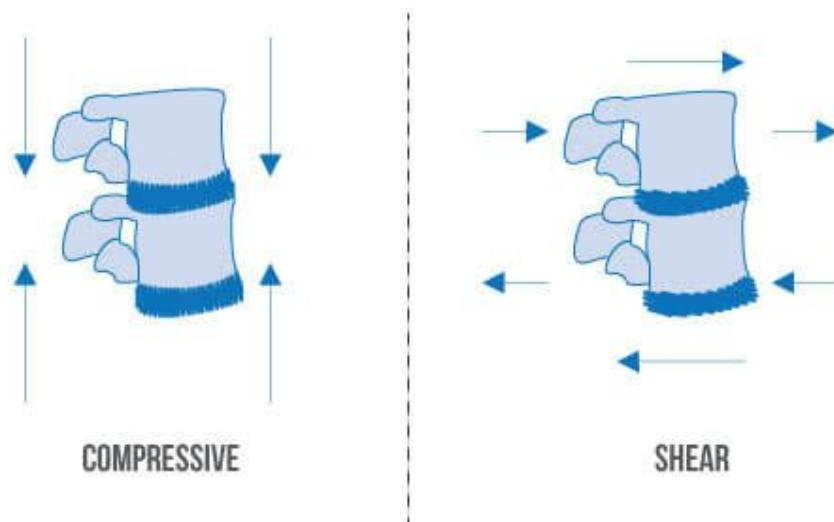
Not much movement is allowed at the junction between each pair of vertebrae, but small movements add up to allow for pretty long ranges of flexion, extension, rotation, and lateral flexion up and down the spine.

The spine naturally has three major curves: a lordotic curve (rounded inward) curve for the lumbar spine, a kyphotic curve (rounded outward) for the thoracic spine, and a lordotic curve for the cervical spine. When we talk about spinal flexion or extension, we're talking about flexion or extension relative to these baseline curvatures. When the spine bends forward relative to these baseline curvatures, it's flexed. When it

moves from a flexed position back toward these baseline curvatures, it's extending. When it moves toward an arched position past these natural curvatures, it's hyperextending. So, for example, when the thoracic spine is fully flat, that means it's hyperextended, but when it's super hunched over, it's flexed. When the lumbar spine is fully flat, that means it's flexed, but when it's super arched, it's hyperextended.

Between each pair of vertebrae is a disc that cushions the spine. These discs hold up really well to compressive forces (pressing the vertebrae together as a result both of the load and the contraction of your spinal erectors) but can have some issues with shear forces (which attempt to slide the vertebrae past each other as a result of the load, your degree of forward lean, and the degree of spinal flexion taking place).

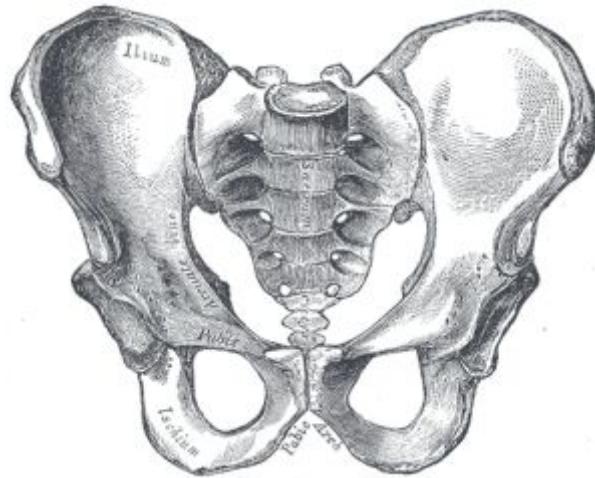
COMPRESSIVE VS. SHEAR FORCES ON THE SPINE



In a properly performed squat, there shouldn't be a meaningful amount of flexion or hyperextension taking place. Your spine should remain rigid and extended to transfer force from your legs and hips into the bar.

Pelvis

Your pelvis is made up of six bones that are, for all intents and purposes, fused together. Each side has an ilium, an ischium, and a pubis. The ilium is the top of the hip, the bony ridge that you feel on your side just below the obliques. The ischium is at the bottom of the pelvis on the back side, and the pubis is at the bottom of the pelvis on the front side in your groin area.



The point where those three bones fuse together is your acetabulum – your hip socket.

There are two other features of your pelvis that are relevant for our purposes here: There's the anterior inferior iliac spine, which is where your rectus femoris (a quadriceps muscle) originates, and there's the ischial tuberosity, which is where the hamstrings originate, and where the adductor magnus primarily originates.

Femur

The femur is your thigh bone, running from your hip to your knee.

There are four main parts of the femur: the head, the neck, the shaft, and the condyles.

The head of the femur is that part that fits into the acetabulum (hip socket); the neck shoots off the head of the femur to connect it to the shaft. Near the junction of the neck and shaft of the femur are the greater and lesser tuberosities, where a lot of your hip abductors and rotators insert. The vasti (your other three quad muscles, apart from the rectus femoris) originate on the shaft of the femur, and your gluteus



maximus inserts on the back and lateral sides of the shaft of the femur. The length of the shaft of your femur largely determines the moment arms you're working with at the knee and hip.

The femoral condyles are at the bottom of your femur where it meets the knee. They're cushioned by your menisci (pads of cartilage in your knee joint) and attached to your tibia by the four major ligaments of the knee: your anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), and lateral collateral ligament (LCL). Your gastrocnemius (your biggest calf muscle) also originates just above your femoral condyles.

Tibia and Fibula

Your tibia and fibula are the bones of your lower leg, running from your knee to your ankle.

The tibia has its own set of condyles that meet the femur at the knee.

Your hamstrings muscles insert just below the tibial condyles and near the top of the fibula, and your soleus (the other major calf muscle, in addition to the gastrocnemius) originates near the top of the back side of your tibia and fibula.



Intervertebral Joints

Intervertebral joints are those between two vertebrae. To briefly recap: Each intervertebral joint is cushioned by a spinal disc, and each allows for only a little bit of flexion, extension, rotation, and lateral flexion, which add up to large ranges of motion in essentially all planes when addressing the spine as a whole.

Hip

The hip is a ball and socket joint, meaning it allows for movement in all planes, including flexion (bringing your knee to your chest), extension (bringing your knee closer to the floor or pushing it behind you), abduction (bringing your knee away from the midline of your body), adduction (bringing your knee toward the midline of your

body), and rotation (internal rotation is rotating the front of your femur toward the midline of your body, and external rotation is rotating the front of your femur away from the midline of your body).

Anatomical variations of the pelvis, hip socket, and femur largely determine how large of a range of motion you'll be able to achieve in each of those movements.

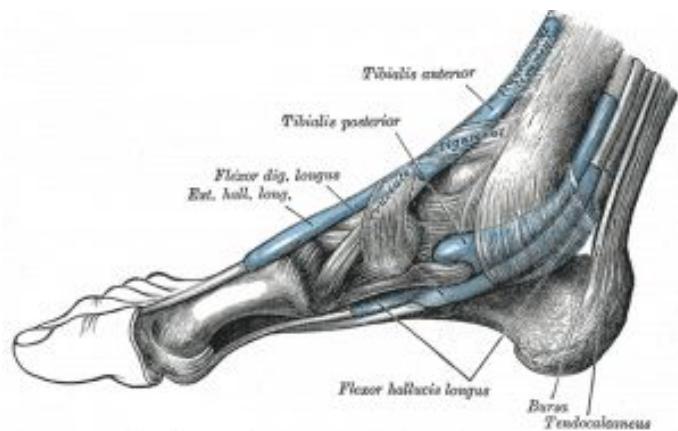
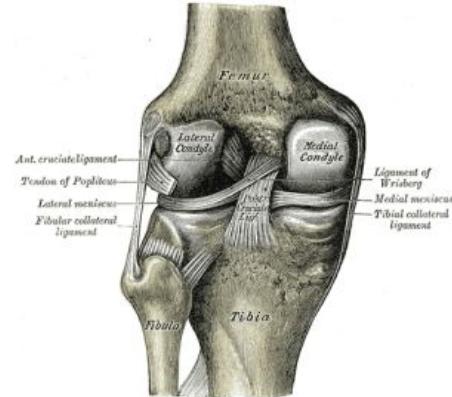
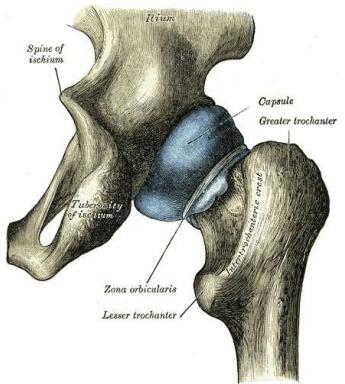
Knee

The knee is essentially a hinge joint, meaning it primarily only allows flexion (like a leg curl) and extension (like a leg extension). It can allow for a *little* rotation, abduction, and adduction, but more than a few degrees of each can put excessive strain on the menisci and your major knee ligaments.

The patella, the knobby little bone at the front of your knee, improves the quads' leverage to pull against the tibia to cause knee extension.

Ankle

The ankle can rotate and bend side to side (inversion and eversion), but for discussing the squat, we really only need to worry about plantar flexion and dorsiflexion. Plantar flexion is pointing your toes away from the rest of your body, and dorsiflexion is the movement you'd perform if you tried to point your toes toward your head.

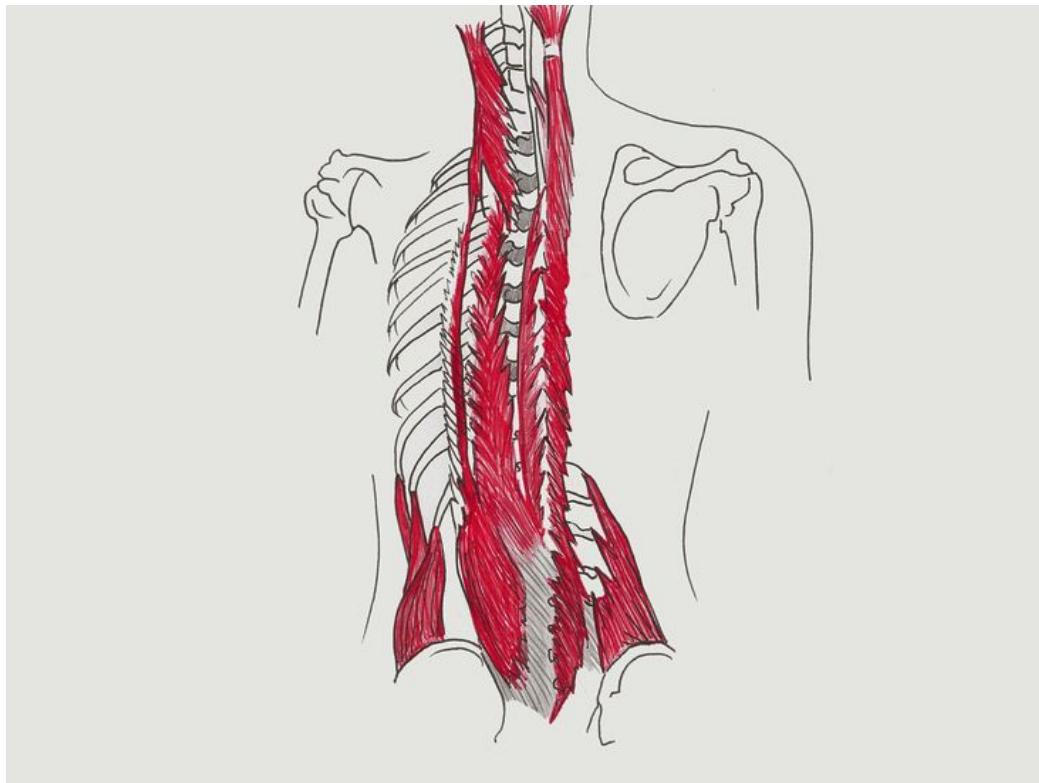


Most people without insanely mobile hips need a fair amount of dorsiflexion range of motion to allow their knees to track forward far enough to break parallel in the squat.

Spinal Erectors

There are several different sets of individual muscles that make up this muscle group, but they all do essentially the same thing, so they're not really worth addressing individually.

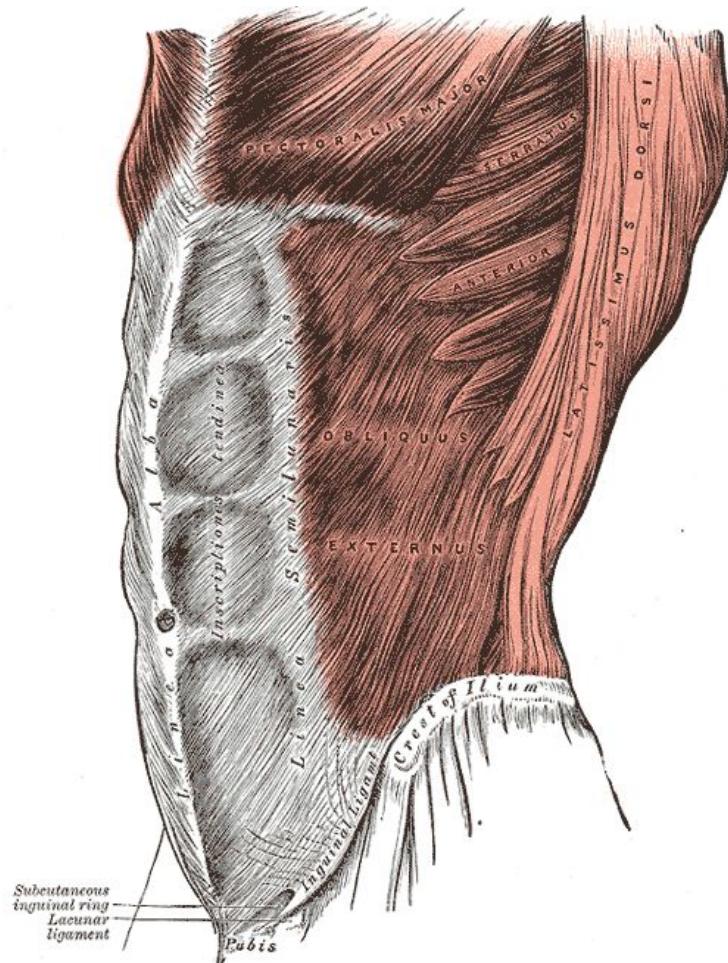
The spinal erectors attach to the top of the pelvis, the ribs, and most importantly, the spine. All of them extend the spine when they contract. Each individual muscle only crosses a few vertebrae, so strength in each region of the spine needs to be addressed specifically. You could have very strong thoracic erectors (upper back) but weak lumbar erectors (lower back) and vice versa.



The "Core"

This is a catch-all term for all of the muscles between the neck and the hips that help keep the torso braced and rigid that don't play quite as direct of a role as the spinal erectors. This would include the obliques, transversus abdominis, rectus abdominis, psoas, lats, and quadratus lumborum.

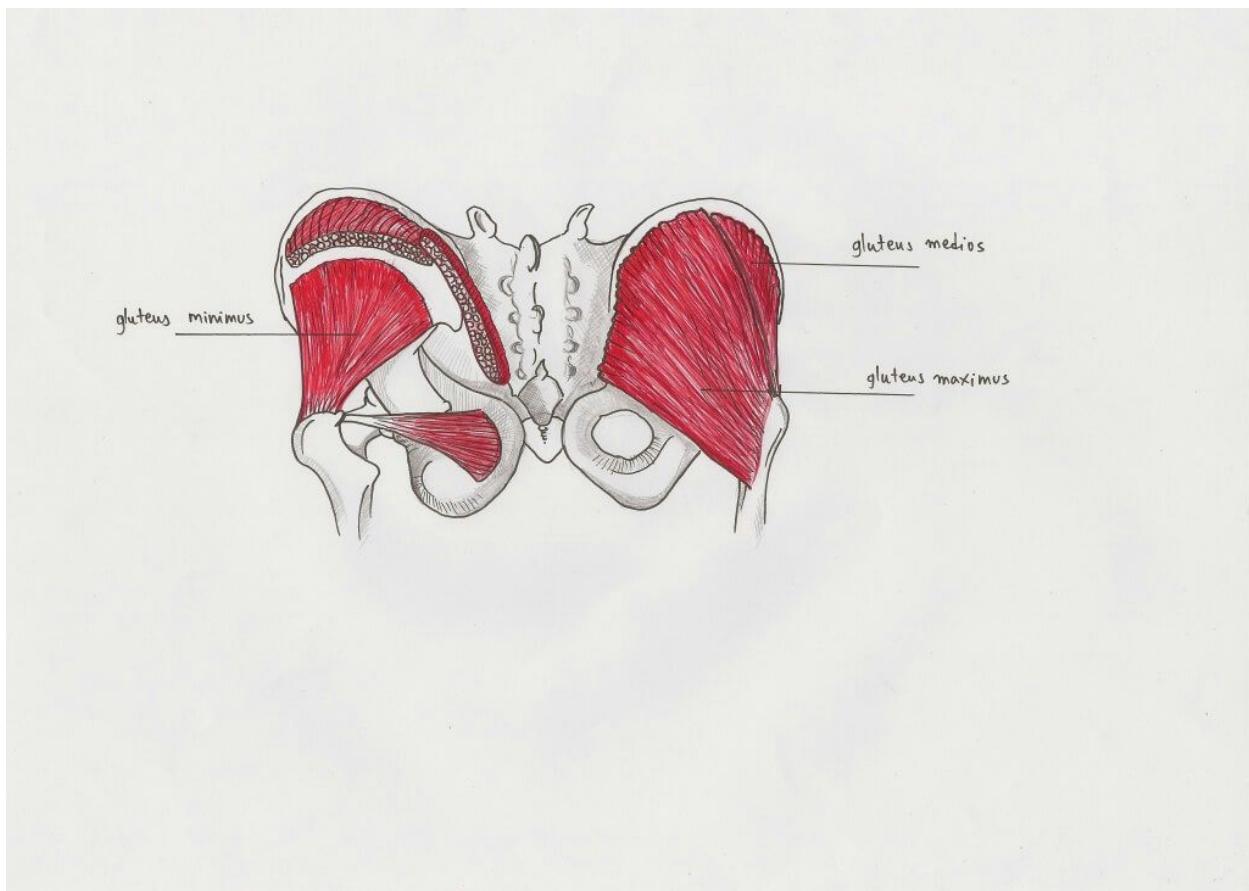
Realistically, none of these muscles are worth addressing specifically, since none of them play a massive role individually. They simply have to be able to produce enough tension to aid the spinal erectors in keeping the spine braced and stable. In the case of the obliques, transversus abdominis, and rectus abdominis, that also includes producing intra-abdominal pressure with the help of the diaphragm and pelvic floor.



Gluteus Maximus

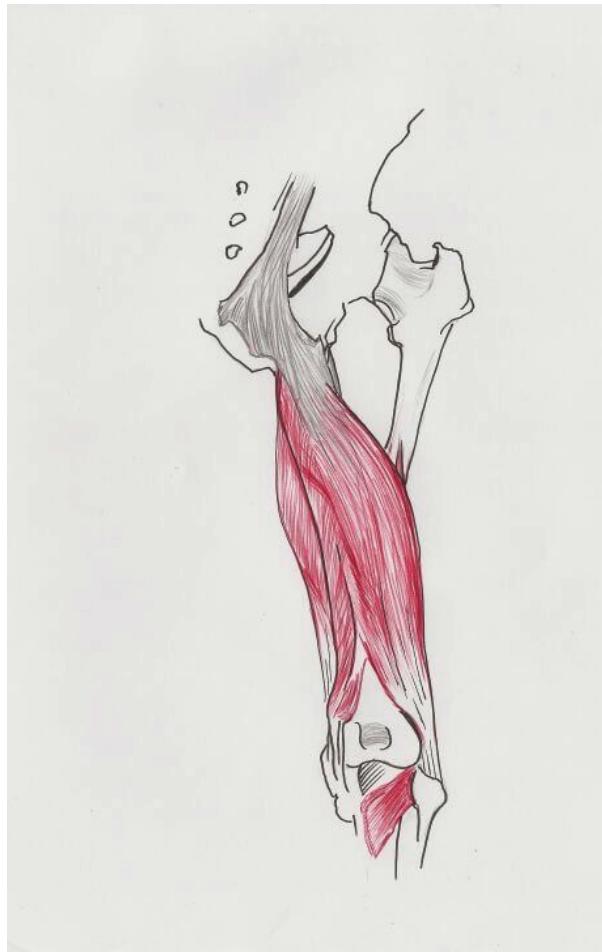
The gluteus maximus is your strongest hip extensor. It originates on the posterior surface of the ilium, and inserts on both the rear and lateral surface of the shaft of the femur, and on the iliotibial band (a thick band of connective tissue on the lateral surface of your leg – the one that probably made you scream in agony if you've ever foam rolled it).

"Origin" refers to the attachment point of a muscle closest to the middle of the body (proximal attachment), and "insertion" refers to the attachment furthest from the middle of the body (distal attachment). When a muscle contracts, it pulls the origin and insertion toward each other.



Hamstrings

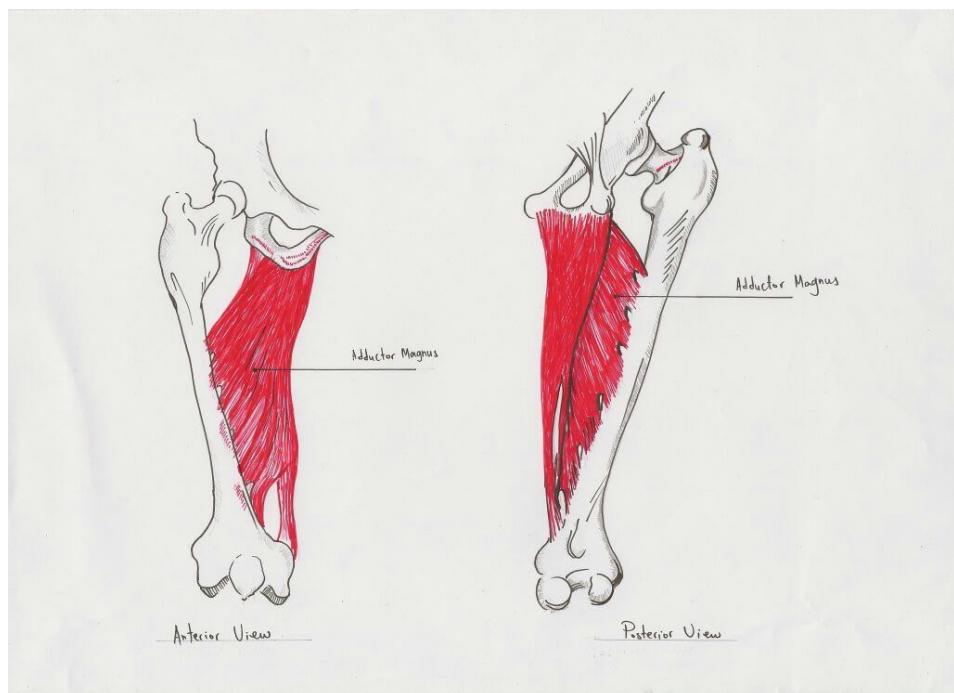
You have three hamstrings muscles – the biceps femoris, the semitendinosus, and the semimembranosus – but for our purposes here, they have essentially the same purpose and can just be treated as one muscle, except for the short head of the biceps femoris, which we don't really even need to discuss. They all originate on the ischial tuberosity and insert just below the knee near the top of the tibia and fibula. Since they cross both the hip and the knee, they cause both hip extension (which you want when standing up from a squat) and knee flexion (which you *don't* want when trying to stand up from a squat). Since their insertion is further from the hip than it is the knee (the internal moment arm is longer at the hip), though, they produce a larger hip extensor moment than knee flexor moment when they contract.



Adductor Magnus

All of your adductors can play a small role in the squat, but the most important by far is the adductor magnus. It's often called the "fourth hamstring" because it originates in essentially the same place on the ischial tuberosity (also extending onto the pubis a bit) and is a powerful hip extensor. Unlike the hamstrings, it inserts on the line aspera on the back of the femur, so it doesn't cross the knee and exert a knee flexor moment.

I don't think the adductor magnus gets quite enough love. When people think hip extension, they instantly think of the glutes and hamstrings, but rarely think of the adductor magnus. However, not to bore you with the details, but it's also a big, meaty muscle, and it's in a very mechanically advantageous position to exert a huge hip extensor moment. It just hasn't been studied directly very much (though a soon-to-be published study shows that it likely produces a larger hip extensor moment than the glutes and hamstrings put together at the bottom of the squat. At the request of the authors, I can't share further details yet, though), which is why I think it's often overlooked.



Quadriceps

[New research](#) has actually shown you have a fifth muscle on the front of your thigh that no one had noticed before, so maybe we should really call these quinticeps. However, that doesn't sound as good, so we're sticking with quads.

Three of your quads – the vastus lateralis, vastus intermedius, and vastus medialis – can all be treated the same way. They originate on the shaft of your femur, and insert near the top of your tibia on the tibial tuberosity (that little bump near the top of your shin, just below your knee) via the patella. All they do is extend the knee.

The fourth is a bit different. The rectus femoris is essentially the inverse of the hamstrings. It inserts on the tibial tuberosity via the patella just like the rest of your quads, but it originates on the anterior inferior iliac spine of the ilium (just above the hip), meaning it can both flex the hip and extend the knee. However, much like the hamstrings had a longer internal moment arm at the hip than the knee, making them more effective hip extensors than knee flexors, the rectus femoris has a longer internal moment arm at the knee than the hip, making it a more effective knee extensor than a hip flexor.

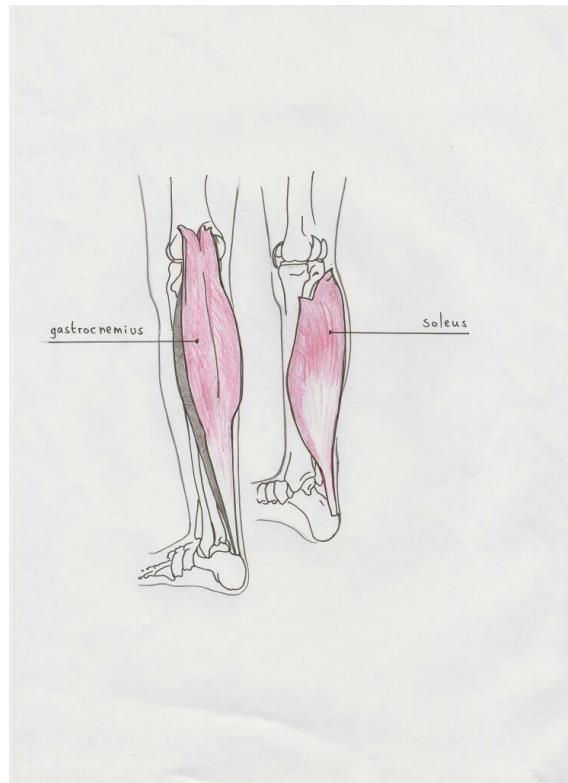


Calves

The last group of muscles we need to address are your calves. You have two major calf muscles, both of which are plantar flexors.

Your soleus originates on the back side of your tibia and fibula, while your gastrocnemius originates just above the condyles of your femur. Both of them insert on your heel via the achilles tendon.

Since the soleus only crosses one joint, it's solely a plantar flexor. Since the gastroc crosses both the knee and ankle, however, it functions as both a plantar flexor and knee flexor.



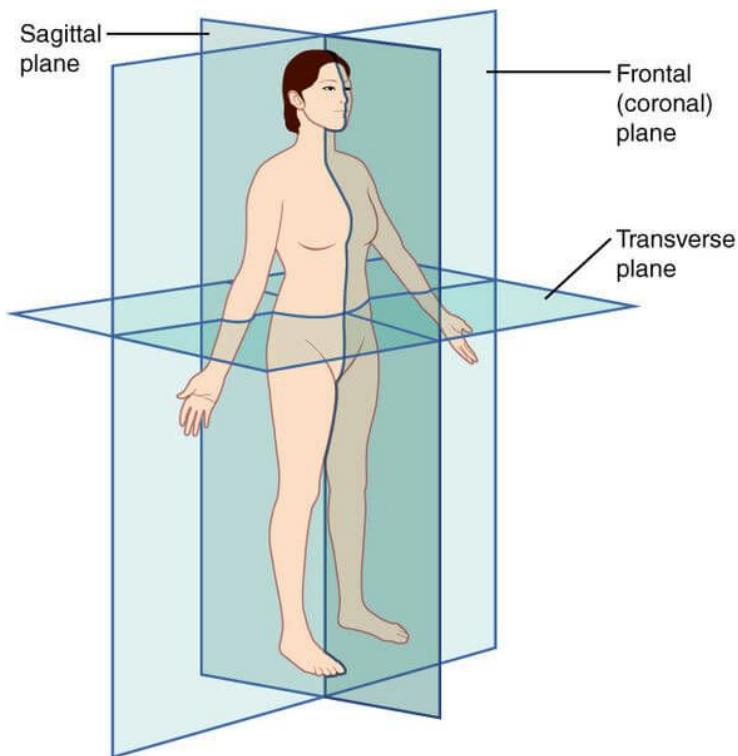
That's enough physics and anatomy for now. You should have a good grasp of the basic forces at play in the squat, and the major muscles, bones, and joints that are interacting to complete the movement.

Biomechanics

This is where things get a little bit more technical.

Planes

To make this section a little easier to understand, you need to understand planes of movement. There are three basic planes: sagittal, frontal, and transverse. The sagittal plane cuts something in half top to bottom and front to back, and it's where flexion and extension take place. The frontal plane cuts something in half top to bottom and side to side, and it's where abduction and adduction take place. The transverse plane cuts something in half front to back and side to side, and it's where rotation takes place.



Here's a crucial point: abduction, adduction, and rotation are defined by the frontal and transverse planes relative to the torso. Flexion and extension, on the other hand, are defined relative to the bones and joints where they're taking place.

Most importantly for the squat, hip and knee flexion and extension are defined by the sagittal plane *relative to the femur*. Imagine a plane that cuts your femur in half front to back and top to bottom. If your knees are pointed straight ahead, then the sagittal plane relative to the femur may be parallel to the sagittal plane relative to your torso, so assessing knee and hip flexion and extension demands simply by looking at the lift dead on from the side will be very accurate. However, if your hips are abducted and externally rotated, the sagittal plane relative to your femur will intersect the sagittal plane relative to your torso, meaning you'd incorrectly estimate knee and hip extensor demands simply by looking at the lift dead on from the side. You need to assess knee and hip extensor demands in three dimensions, not just two. Escamilla [previous demonstrated](#) how assessing knee and hip extensor demands in just two dimensions could produce pretty large errors when analyzing the squat



In the frontal plane relative to the body, but still in the sagittal plane relative to the humerus, so it's still elbow flexion and extension.

Here's an easy way to think about this: There are probably 1,000 types of curls. There are barbell curls, concentration curls, preacher curls, and the list goes on. I don't think anyone would argue that a curl isn't essentially pure elbow flexion and extension. However, when the shoulder is internally rotated (as in a concentration curl), the forearm is moving in the frontal plane relative to the body. I don't think anyone would argue that a concentration curl is actually elbow abduction and adduction. That's because elbow flexion and extension are defined relative to the humerus, and you're always performing curls in the sagittal plane relative to your humerus. The exact same principle is in play with the squat.

Basic Demands in the Squat

There are four basic challenges you need to overcome in the squat: a spinal flexor moment, a hip flexor moment, a knee flexor moment, and an ankle dorsiflexor moment.

The spinal flexor moment depends on two things:

1. The horizontal distance (perpendicular to gravity) in the sagittal plane (relative to the torso) between the bar and any intervertebral joint.
2. The load on the bar.

Therefore, there are three things that increase the spinal flexor moment, all other things being equal:

1. Moving the bar higher on the back or in front of your body.
2. Adding more weight to the bar.
3. Inclining your torso farther.

The ankle dorsiflexor moment depends on two things:

1. The horizontal distance in the sagittal plane (relative to the tibia) between the center pressure on the foot and the middle of the ankle joint.

2. The total load (bar weight and body weight).

Therefore, there are two things that increase the ankle dorsiflexor moment:

1. Adding more weight to the bar
2. The center of pressure shifting further forward on the foot

The hip flexor moment depends on two things:

1. The horizontal distance in the sagittal plane (relative to the femur) between the center of mass of the system (the bar plus the weight of your body above the hip) and the hip.
2. The total load above the hip (bar weight and body weight).

Therefore, there are three things that increase the hip flexor moment:

1. The center of mass of the system shifting further forward or the hips shifting further backward.
2. Adding more weight to the bar.
3. Depth. The front-to-back length of the femur in the sagittal plane increases the closer you get to parallel, so the hip and/or knee flexor moment arms increase in length too.

The knee flexor moment depends on two things:

1. The horizontal distance in the sagittal plane (relative to the femur) between the center of mass of the system (the bar plus the weight of the body above the knee) and the knee.
2. The total load above the knee (bar weight and body weight).

Therefore, there are three things that increase the knee flexor moment:

1. The center of mass of the system shifting further backward or the knees shifting further forward.
2. Adding more weight to the bar.
3. Depth. The front-to-back length of the femur in the sagittal plane increases the closer you get to parallel, so the knee and/or hip flexor moment arms increase in length too.

The demands on the ankle and spine can be addressed independently, but the demands on the knee and hip are intrinsically linked to each other.

Knee flexor moment = load x horizontal distance between the center of mass and the knee.

Hip flexor moment = load x horizontal distance between the center of mass and the hip.

So, as the center of mass shifts forward, the knee flexor moment decreases and the hip flexor moment increases, and vice versa.

From this, we can see another cool identity that simplifies things a lot.

Horizontal distance between the center of mass and the knee + Horizontal distance between the center of mass and the hip = front-to-back length of the femur in the sagittal plane.

You can find the front-to-back length of the femur in the sagittal plane by taking the cosine of the angle the femur forms with the ground.

So...

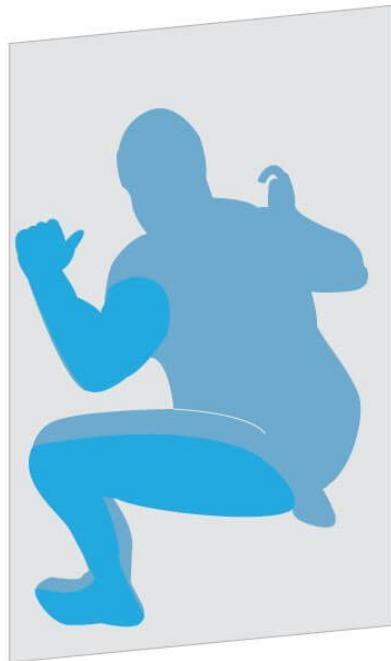
Equation: Knee + hip flexor moment = load x femur length x cos(femur angle)

In other words, nothing you do really changes the summed knee and hip extensor demands in the squat. When the femur is parallel to the floor, total extensor demands

peak, and they're the same for any given load regardless of bar position, stance width, or footwear. Likewise, total extensor demands for the knee and hip are the same between different squat styles at any discrete depth, assessed by femur angle relative to the floor.

This little fact simplifies things dramatically. Later, we'll discuss why you can still squat more with certain techniques even though the total demands from the waist down are identical.

SAGITTAL PLANE RELATIVE TO THE FEMUR



Biarticular Muscles

There's one more thing to address that's simple to understand, but not immediately obvious: the role of the hamstrings and rectus femoris.

Remember, they're those pesky two-joint muscles (also called biarticular muscles) that do one thing we want – knee or hip extension – along with one thing we don't want – knee or hip flexion.

Also remember that their counterproductive functions don't matter *too* much because the hamstrings insertion is much farther from the hip than the knee, making it a stronger hip extensor than knee flexor, and vice versa for the rectus femoris.

However, they do have a really cool property: They help distribute the extensor moments produced by the other knee and hip extensors from one joint to the other.

When the knee extends, it pulls the insertion of the hamstrings along with it. The movement at the knee is transmitted as a force up the hamstrings, helping to extend the hip. When the hips extend, that movement is transmitted as a force down the rectus femoris, helping the knee to extend.

These actions help distribute the forces efficiently throughout the system. The hip extensors can actually help out a bit at the knee, and the quads can actually help out a bit at the hip.

When you look at studies that measure muscle activation in the squat (one example is shown later on, and many more are linked at the end), you see that muscle activation is actually pretty similar between different squatting styles, including those that *look* a lot more "[knee dominant](#)" or "[hip dominant](#)." Generally, there are no differences in muscle activation, or at the very least, they're much smaller than you'd anticipate just by looking at knee and hip extension demands. However, when you realize that these biarticular muscles are letting the hip extensors help out at the knee and vice versa, those minimal-to-nonexistent differences in muscle activation make a lot more sense.

This illustration from a study by [van Ingen Schenau](#) illustrates how this concept also applies to jumping – the quads aiding in plantar flexion via the gastrocnemius. The same concept applies at the knee and hip via the hamstrings and rectus femoris.

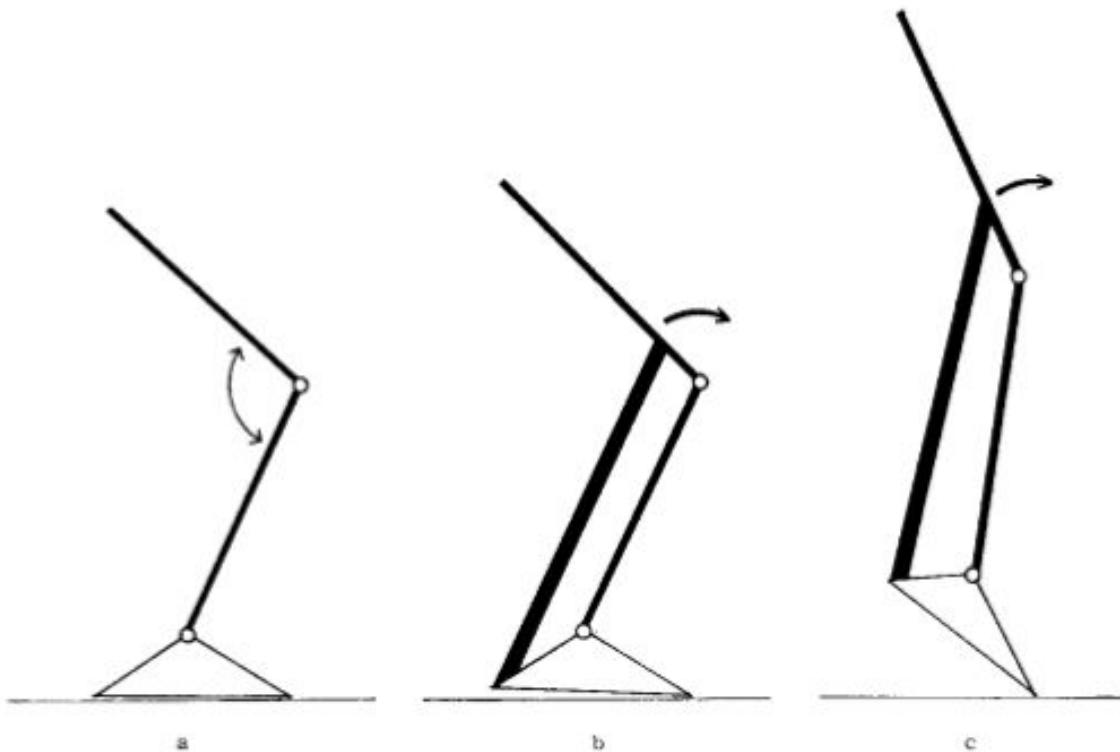


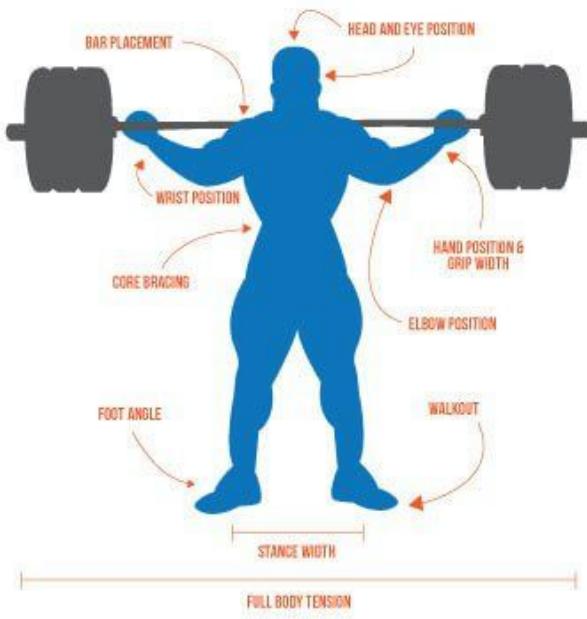
Fig. 6. The bi-articular gastrocnemius muscle couples knee extension to plantar flexion. A continuing knee extension (supported by the knee extensors) now supports plantar flexion since the origin of the gastrocnemius (on the upper leg) pulls on the calcaneous. Activation of the gastrocnemius in this phase of the jump thus decreases the net joint power in the knee and increases the joint power in the ankle. This phenomenon is called a transport of power from knee to ankle.

Now it's time to actually get into the squat itself. After discussing the basic movement, we'll revisit some of this material to help you address and correct weaknesses, and to answer some basic questions about the squat and how to optimize it for yourself.

Squatting: The Setup

There are three key components of the squat: the setup, the descent (eccentric), and the ascent (concentric).

EVERYTHING THAT GOES INTO A SQUAT SETUP



There's a little bit of variation regarding the descent and the ascent; there may be a cue here or there that works well for some people and not so well for others. However, they are pretty similar for most people. They may look a bit different, but the underlying cues and demands are quite similar.

The setup, on the other hand, has a lot more variation. People feel the most comfortable and squat the best with different bar positions, different stance widths, different grip widths, etc.

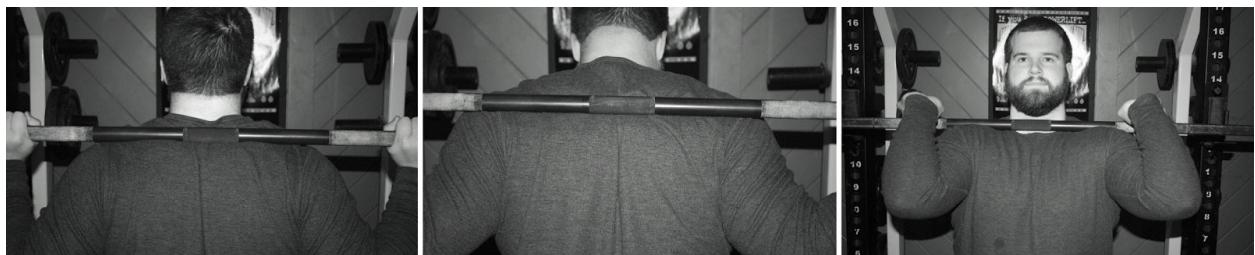
For most of the topics in this section, there are very few black and white rules or distinctly better or worse options. There are just several different approaches that are more or less effective for different people. This section covers that variety, discusses the advantages and disadvantages of various techniques, and ultimately aims to give you the

tools to troubleshoot your setup to optimize it for yourself, since there's no one-size-fits-all solution.

A couple of considerations in this section will be explored in more depth later on (bar position and stance width particularly), but in this section, we're just hitting the high points.

Bar placement

The first consideration for your setup is bar position. There are three basic bar positions for the squat: high bar, low bar, and front. In the high bar squat, the bar is resting on your traps; in the low bar squat, the bar is resting across your rear deltoids; and in the front squat, the bar is resting across your anterior deltoids or in the cleft between your anterior deltoids and your traps.



I'll also note that the line between the high bar squat and the low bar squat is a hazy one. You could draw an arbitrary line at the spine of the scapulae (since the posterior deltoids originate on the bottom of the spine of the scapulae, and the upper fibers of the traps insert on the top of the spine of the scapulae), but is there a fundamental change in the lift when you move the bar up or down half an inch across the spine of the scapulae? Not really. I'll treat them as distinct entities in the rest of this guide since they're usually demarcated as different exercises. However, in practice, the differences between them are very small; just a shift in bar position of 2-3 inches for most people, leading to 5-10 degree changes in torso and joint angles (a bit less forward lean, a bit more knee flexion, and perhaps a bit less hip flexion for the high bar squat vs. the low bar squat) unless you're purposefully cuing them differently.

In the high bar squat, the bar rests across your traps. Depending on how jacked you are, your traps may cover a fair amount of real estate. See where the bar feels most comfortable. It may feel best higher up on your traps, or it may feel best resting a bit lower across the meat of your traps. Also see how it feels actively shrugging to tense your traps versus relaxing them a bit more. I personally prefer the bar on the meat of my traps, with my traps relaxed a little bit so the bar can sink in. Your mileage may vary.

The biggest thing you want to avoid when situating the bar for the high bar squat is letting it grind into your C7 spinous process – the little bony bump at the base of your neck. When people complain of neck pain when squatting and think they need to use a bar pad to alleviate the discomfort, this is generally the mistake they're making. If you want to squat with the bar that high on your traps, try shrugging up to tense your traps harder so the bar can rest above that bony protuberance or if you'd prefer, lower the bar a bit onto the meat of your traps.

In the low bar squat, the bar should be resting on your posterior deltoids. Similar to getting pain due to the bar pressing into your C7 spinous process when high bar squatting, some people get discomfort in their shoulder blades when low bar squatting. That generally comes from letting the bar rest directly on the spine of the scapulae. Just moving the bar a teensy bit higher (which makes it the lowest possible high bar squat, though the distinction *really* doesn't matter) or lower should take care of that discomfort. For both the high bar and the low bar squat, you should actively pull your shoulder blades together.

Finally, in the front squat, the bar should be resting between your anterior deltoids and the front of your traps. If you feel discomfort on your AC joint (at the top of your shoulder) or your sternoclavicular joint (where your collarbone meets your breast bone) ... then I can't really help you. Getting slightly more jacked anterior deltoids can help a bit, but really, front squats are just uncomfortable until you deaden the nerves under the

skin where the bar rests. You're almost guaranteed to get bruises somewhere along your collarbone, especially when you first try them.

Many lifters have a hard time finding a secure position for the bar when they first try front squatting. They'll find that the bar keeps trying to slide down their shoulders, and that it's putting a lot of pressure on their wrists. The biggest culprit is scapular position. Experienced powerlifters *especially* get used to doing everything with their scapulae retracted (pulled back, like you're trying to pinch a pencil between your shoulder blades). However, when you retract your scapulae, your clavicles move back along with them. You want to *protract* your scapulae (like you're trying to pinch a pencil between your pecs), so your clavicles will shift forward as well. That should put your anterior deltoids far enough in front of your neck that you have a nice shelf to rest the bar across. This isn't any more comfortable, but it *is* much more secure, and the bar will be much less likely to slide down your shoulders.

Hand position

The next topic is hand position: How wide or narrow do you want your hands on the bar?

In general, for the high and low bar squat, a narrower hand position will help you keep your upper back a little tighter and more stable. When you bring your hands in, your scapulae naturally have to retract harder (so your middle and lower traps will be tighter, along with your rhomboids), and your shoulders will naturally have to adduct (tensing your lats a bit). With a wider hand position, you can still *consciously* tense your upper back muscles, but it's a lot easier and feels more natural to create upper back tension with your hands closer.

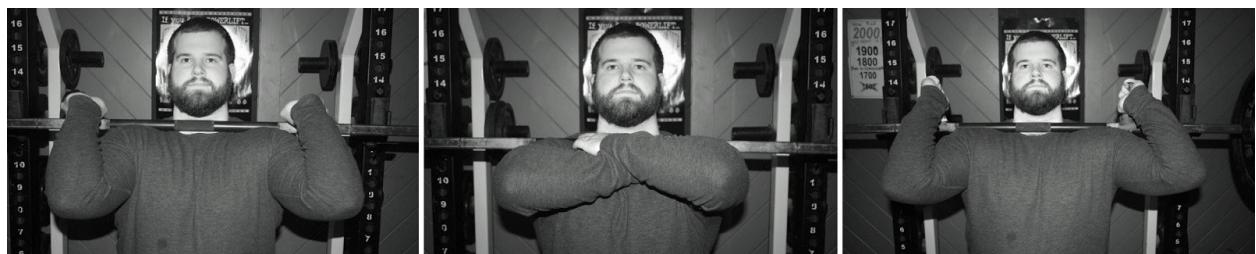
In general, your hands should be as close as you can comfortably get them. If you can get them closer without pain in your wrists, shoulders, or elbows, or just *feeling* super uncomfortable, then you'd probably benefit a little from doing so.

For the front squat, there are three basic hand positions.

The first is the front rack position. This is the most common among weightlifters. Your hands should be slightly wider than shoulder width, keeping as many fingers on the bar as possible while front squatting. If that's only two or three fingers, that's fine: Your shoulders should be supporting the majority of the load, not your hands and wrists.

The second is the arms-crossed position. This is most common with bodybuilders and some powerlifters. Once you get the bar situated across the front of your shoulders, you simply cross your arms, keeping your hands a bit inside your shoulders, and hold onto the bar that way. Most people will feel a bit more secure if they can work on their front rack position so they don't have to front squat this way, but some people who are exceptionally jacked or who have shoulder mobility restrictions may feel best front squatting with this hand position.

The last is with straps. This is a good compromise for people who have poor mobility, but who still want to approximate the front rack position. Simply wrap wrist straps around the bar and grip onto them, as close to the bar as possible. Pull the straps tight so they don't slide back and forth while you're trying to front squat.



Wrist position

Wrist position isn't an overly important consideration for the back squat if you're creating a stable enough shelf for the bar with your traps or rear delts. If the traps or rear delts are supporting (essentially) the entire weight of the bar, and the bar isn't

sliding down your shoulders, then it doesn't matter very much whether your wrists are kept straight, or if you let them cock back.

Many people don't create a stable shelf for the bar, so the bar presses down and back into their hands when they squat. When this happens, it can cause wrist discomfort if the wrists are cocked back. If you *do* get wrist discomfort when squatting, getting back to a neutral wrist position can help alleviate that discomfort.

There are three things you can do to get your wrists back to neutral when squatting, if squatting bothers your wrists.

1. Just simply focus on keeping your wrists straight. If you have the mobility to keep your wrists neutral but you simply don't do it (perhaps because you never knew to try), this is an easy fix.
2. Widen your grip on the bar. Remember, your grip should be as close as it can get *without* pain in your wrists, elbows, or shoulders. Generally, people's wrists will cock back when they're squatting due to limited shoulder mobility. They can't externally rotate their shoulders enough to get their hands behind the bar with room to spare, so they "cheat" and cock their wrists back to compensate. By widening your grip a bit, it's easier to externally rotate your shoulders enough to get your hands behind the bar with your wrists straight.
3. Put your thumb over the top of the bar (and maybe put your pinky under the bar). This can be especially helpful for low bar squatters. If you wrap your thumb around the bar, the juncture between your forefinger and thumb needs to be below the bar (obviously). If you don't wrap your thumb around the bar, you don't need to get as much radial deviation from your wrists (wrists bent in toward the middle of your body), and you don't need to get your hand quite as low, which means you don't have to externally rotate your shoulder quite as much. When you do this, the bar will just rest across the meaty part of your palm instead of needing to grip it with your fingers, and instead of holding onto the bar by

gripping it, you push it forward into your shoulders to keep it from slipping. If putting your thumb on top of the bar doesn't quite take care of this issue for you, you can keep your wrist in a slightly more neutral position by also putting your pinky underneath the bar.



Just a note: Wrist pain and issues keeping the wrists straight are much more common with the low bar squat than the high bar squat, since external rotation demands at the shoulder are greater with a lower bar position.

For the front squat, your wrists will always be cocked back if you're holding the bar in a front rack position. Generally this won't cause wrist discomfort unless your wrist flexors are *super* tight, or if you don't have a solid shelf for the bar to rest on and it starts sliding, causing your hands and wrists to bear more of the load. If that happens, it's more of an issue with having a solid shelf to rest the bar on. Protracting your shoulder blades and driving your elbows higher should help.

If you're still getting wrist pain front squatting after trying those things, then feel free to hold the bar by either crossing your arms or using straps, provided you're not front squatting for weightlifting (in which case, you *really* need to make sure you have a solid front rack position).

Elbow position

Your elbow position in the back squat largely depends on comfort.

In general, your elbows should be down and pulled into your sides. I like to use the cue, "scratch your rib cage with your elbows." This will help create lat tension to aid in torso rigidity and upper back tightness.

However, especially for the low bar squat, some people may benefit from driving their elbows up behind the bar. The reason for this is simple: The bar is resting on your rear delts in the low bar squat, and people with small rear delts will simply have a hard time creating a stable shelf for the bar to rest on without sliding.

Driving your elbows up behind the bar *can* cause some people's chests to cave forward. This is especially true for people with poor shoulder mobility, who need to flex their thoracic spine to get their elbows higher. Conversely, many people who feel like they're getting caved forward by a squat can save the lift by aggressively driving their elbows down and forward to stiffen their upper back and keep their chest from folding forward.



In the front squat, your elbows should be as high as possible. Driving your elbows up will help keep your thoracic spine from flexing, and it'll give you a better shelf for the bar to rest on by flexing your front delts a little harder.

Walkout

At this point, you should have the bar set comfortably and stably (or maybe not-so-comfortably, but at least stably for the front squat) across your shoulders, so you're ready to walk out with the bar.

The first thing you need to square away is the height of the hooks you're squatting out of. You should be able to get the bar over the hooks comfortably without having to half squat the weight just to unrack it, or rise up on your toes to get the bar over the hooks. This should be common sense. However, I still see a lot of people who set the hooks too high so they have to raise up on their tiptoes to unrack the bar. Not only is this stupid – it's dangerous. Starting with the hooks too low is a bit less common, and it's not as much of a concern, but it'll mean wasted energy unracking the bar before you're even ready to squat it.

The second order of business is getting your feet set under the bar. This is primarily a matter of comfort. Most powerlifters unrack the bar with their feet square and set beneath their hips or shoulders. Many weightlifters, on the other hand, will unrack the bar with a slightly staggered stance.



Realistically, it doesn't matter very much how you set your feet to unrack the bar in any general sense. If you're squatting a ton of weight, or if you feel less stable with a staggered stance, then you're better off unracking the bar with your feet squared. Otherwise, just go with whichever approach you're most comfortable with.

Unrack the bar by driving your shoulders up into the bar aggressively. A lot of people find that, especially with very heavy loads, unracking the bar aggressively makes the weight feel less intimidating than gingerly unracking the bar. Start with your hips a bit behind the bar, take a deep breath into your stomach, tense your back, and drive the bar

up off the hooks by driving your hips under the bar and pushing the floor away from you.

You should walk the bar out of the rack as efficiently as possible so that you waste minimal energy before you actually get down to the business of squatting. This means taking as few steps as possible. You want to get far enough away from the rack that you won't accidentally hit the hooks when you're squatting, but you don't want to expend more energy than necessary, or take huge steps that could throw you off balance.

The first walkout is the two-step walkout. Once you unrack the bar, take a little step back with one foot, take a little step back with your second foot, and make a small adjustment in the direction your toes are pointed if needed. If you're unracking the bar with a staggered stance, then take your first step back with your front foot. This is most common with narrow stance squatters.

The second walkout is the three-step walkout. This is the most common with wider stance squatters. Once you unrack the bar, your first two steps are the same, and then you widen out your stance with your third step. This is much easier for most people than starting with a wide stance and taking two awkward steps backward.

Stance width

The next issue is finding your stance width.

There are two main considerations here: comfort and carryover.

Comfort

No need to complicate this. Simply play around with your stance width and see what feels the best for you. You can do this unweighted if you're new to squatting, or with a reasonably heavy but not overly challenging load (think 70-80% of your 1rm) if you're more experienced, but think you may want to change your squat stance. Just start around shoulder width and squat down. See how that feels. Then try an inch or two narrower. Then an inch or two wider. Try to drive your knees out versus letting them

track straight ahead and see what feels the strongest and most comfortable. Let your body tell you how to squat. See how deep you can squat with each stance width without your back rounding, and see how stable and comfortable you feel in each position. Stick with the one that gives you the best combination of depth and comfort.

Carryover

This is only a consideration for people who are squatting for something other than the squat itself. Thinking about the carryover you'll get from squatting to some other athletic endeavor is particularly an issue with weightlifters who primarily back squat to improve their leg strength for the snatch, and front squat to improve their leg and torso strength for the clean. People who are squatting primarily to improve their vertical leap may want to consider carryover as well.

In general, you'll get the best carryover if your squat width is similar to your stance width in whatever movement you're hoping it will carry over to. So, you should back squat with your feet the same width they'd be when catching a snatch, your foot position should be the same when you front squat and when you catch a clean, and your stance width when squatting (in any manner) should be similar to your stance when jumping (feet below hips or just slightly wider, typically).

This isn't necessarily a *massive* concern, because the general lower body strength you build squatting will carry over to other athletic endeavors regardless of how closely your stance when squatting mimics your stance in other movements. However, it will help a little bit.

One final consideration for powerlifters: Your goal in competition is simply to squat as much weight as possible, and you'll generally be able to squat a bit more with a shorter range of motion. You should break parallel convincingly enough to get white lights from the judges, but not excessively deep. Unlike ice skating, you don't get bonus points for style.

You'll also generally squat more if you can bottom out in the squat versus reversing the weight above your full bottom position (assuming you're breaking parallel in both circumstances), because bottoming out allows you to take advantage of the stretch reflex, which gives you a little more *oomph* to start building momentum.

With that in mind, powerlifters whose bottom position is considerably deeper than parallel, approaching ass-to-grass, should also experiment to see how wide they can squat while still breaking parallel. A wider stance will naturally limit depth, letting you still benefit from bottoming out and taking advantage of the stretch reflex, without going unnecessarily deep. This can be very helpful for some people, but some people's hips will protest. Either way, it's worth a shot to see if it can help you put up bigger numbers on the platform.

Squatting wider also has two advantages apart from simply limiting range of motion:

1. *A wider stance width will naturally train your adductors more, particularly your adductor magnus.* There's no reason to believe that a wider stance would decrease how much your glutes or hamstrings could contribute to the lift (in fact, two studies – [one](#), [two](#) – found that glute activation was a bit higher with a wider stance), and it very well *may* increase how much your adductor magnus can contribute to the lift. Total knee and hip extension demands would be pretty similar, but you *should* be able to produce a larger hip extensor moment with a wide stance. This isn't true for all people, but it is true for many.
2. *A wider stance can make the lift slightly easier on your back.* Unlike knee and hip extensor demands, spinal extension demands only need to be addressed in two dimensions. With a wider stance and more hip abduction, making the femur "shorter" front to back, you generally don't have to incline your torso quite as much to keep the center of pressure over the middle of your foot, decreasing spinal extension demands.



Front

Side

Close-, moderate-, and wide-stance squats. The width you squat with depends on your personal anatomy and your training goals.

Foot Angle

There are two main considerations when talking about how far out you should point your feet: knee health and balance.

Knee Health

In general, your best bet is to let your hips and knees determine your foot angle.

Once you've experimented with your stance width and how aggressively you abduct your hips (driving your knees out vs. letting them track forward), simply adjust your foot angle so that your toes and knees point the same direction. So, if you have a wider stance with more hip abduction (which typically go hand in hand, but not always), your toes should point out more, and if you have a narrower stance with less hip abduction, your toes should be closer to straight ahead. In a "normal" squat for someone near the middle of the anatomical bell curve, that generally means having your toes pointed out 15-20 degrees – not straight ahead, but not turned out a ton. On the other hand, for squatters like myself with a wider stance and more hip abduction, there's nothing wrong with having your toes pointed out at closer to 30-45 degrees.

You want your knees to track over roughly your first or second toe. Rather than squatting with your feet turned out to a predetermined degree or arbitrarily pointed

straight ahead and forcing your knees and hips to follow along, you're better off seeing what hip and knee position feels the strongest and most comfortable, and letting that determine how far out you point your feet. If your knees track a little bit inside your big toe or a little closer to the outside of your foot, it's not the end of the world as long as it doesn't come along with knee pain. However, you're probably better off just pointing your toes in whatever direction your knees are tracking, and not worrying about it past that.

Balance

The one exception to the general rule of letting knee position dictate toe position is for really wide-stance squatters with a lot of hip abduction.

Many people start having balance issues if their feet are turned outward 45 degrees or more, simply because their feet are then "shorter" front-to-back when looking at them from the side. Sometimes, this can make it easier to lose your balance forward or back if you misgroove the lift.

If that happens to you, then just point your toes a bit further ahead. Your knees will track a bit outside your first or second toe, but as long as you don't get knee pain, that's probably fine. You could also bring your stance in a bit and not abduct your hips quite as much.

Bracing

Bracing your torso is crucial for a big squat. It doesn't matter how strong your legs and hips are if that force can't make it to the bar through a rigid torso (hello people who leg press 800lbs and only squat 225).

There are two key factors for developing torso rigidity: spinal extension strength, and intra-abdominal pressure.

The first factor – spinal extension strength – is straightforward: Is your back strong enough to stay extended with the weight, or does the weight cave you forward? For

more experienced lifters, this is typically a strength issue, and it can go a long way toward explaining performance differences between the different squat styles. For newer lifters, though, it can be a control/skill issue because they are simply not accustomed to tensing their spinal erectors and maintaining that tension with a loaded bar on their shoulders. Most people with some degree of innate kinesthetic sense will figure out how to contract their spinal erectors to keep their back rigid pretty quickly, though. A loaded bar across your shoulders makes for a good teacher.

The second factor – intra-abdominal pressure – isn't quite as straightforward. To the best of my knowledge, there isn't much research concerning different torso bracing cues and their effects on intra-abdominal pressure. Here's what we do know:

1. Intra-abdominal pressure is higher [with a belt than without one](#). This is the primary reason people can squat more with a belt.
2. Intra-abdominal pressure is higher when you take a diaphragmatic breath than when you "breathe into your chest/shoulders." When you inhale, your stomach should inflate to the front and sides (which has been described as "360 degree expansion" by Chad Smith and "inflate your obliques" by Chris Duffin), rather than your chest and shoulders rising.
3. Intra-abdominal pressure is higher when you hold your breath and use the valsalva maneuver (like you're trying to forcefully exhale while closing off your throat so no air gets out).

Those three things will account for the majority of the intra-abdominal pressure you can produce.

There are also people who take the position that purposefully pulling your ribs down (without rounding your spine) and keeping your pelvis neutral (most people start the squat in anterior pelvic tilt – like you're trying to stick your butt out) will help you create

more intra-abdominal pressure. As the thinking goes, when the diaphragm and pelvic floor at the top and bottom of your abdominal cavity are facing each other, then your diaphragmatic breath will create more intra-abdominal pressure. That's in contrast to the more standard cue of arching your back hard throughout the lift, which will also let your ribs flare up, and your pelvis go into anterior tilt, so that your diaphragm and pelvic floor wouldn't be facing each other.

To the best of my knowledge, this question has never been studied. There's an intuitive appeal to the squatting with the ribs down and the pelvis in neutral, but I'm not sure there's a meaningful difference in the real world, at least in any general sense. One advantage to purposefully squatting in neutral is that it lets you squat a bit deeper. When your pelvis is anteriorly tilted, you're starting the movement already in a little bit of hip flexion, and reaching or approaching end-ROM for the hips is what limits most people's squat depth, so many people bottom out a little higher when focusing on arching their back hard. On the other hand, an advantage of focusing on arching is that it effectively ensures you're actively keeping your spine extended (which is the whole point of bracing, after all). There are plenty of good lifters who use both techniques, so this is an instance where your best bet is probably just to experiment for yourself and see which cue helps you feel tighter.

One final point about bracing: It's not just "tensing your abs," and realistically, abdominal strength probably doesn't impact squatting to any meaningful degree.

To start with, there's the simple mechanical explanation: your abs are spinal flexors, and when you squat, you're trying to keep your spine extended against the flexion moment imposed by the bar. Some degree of abdominal contraction is necessary to produce intra-abdominal pressure, but it's more like you're bracing to take a punch (if you're squatting beltless), not like you're trying to do a crunch. If you're squatting with a belt, it's more like trying to inflate your torso to press against your belt, not to flex your abs.



The harder your abs (spinal flexors) contract, the harder it is for your spinal erectors to keep the spine from flexing.

Furthermore, multiple studies have measured activation of various abdominal muscles in the squat, and activation is pretty low on the whole – certainly nowhere close to what you'd expect from traditional "core" exercises like sit-ups or planks. This implies that the actual strength of your abdominal musculature probably won't limit your performance in the squat, since they're not being stressed anywhere close to their limits. [This article](#) explains this concept in more detail, complete with citations.

Finally, in [research on highly trained powerlifters](#) looking at the correlations between performance in the squat and the thickness of various muscles, there wasn't a particularly strong correlation between abdominal muscle thickness and squat performance.

All of this means that developing torso stiffness for the squat depends on your spinal erector *strength*, combined with the *skill* of bracing your core to create intra-abdominal pressure, but that the strength of your abs, obliques, and transversus abdominus probably isn't going to limit you.

Creating full-body tension

At this point, you've gotten the bar set across your shoulders, you've sorted out your hand and elbow position, you've walked the bar out, found your stance width and foot position, and you've taken a deep diaphragmatic breath (into your stomach) to create

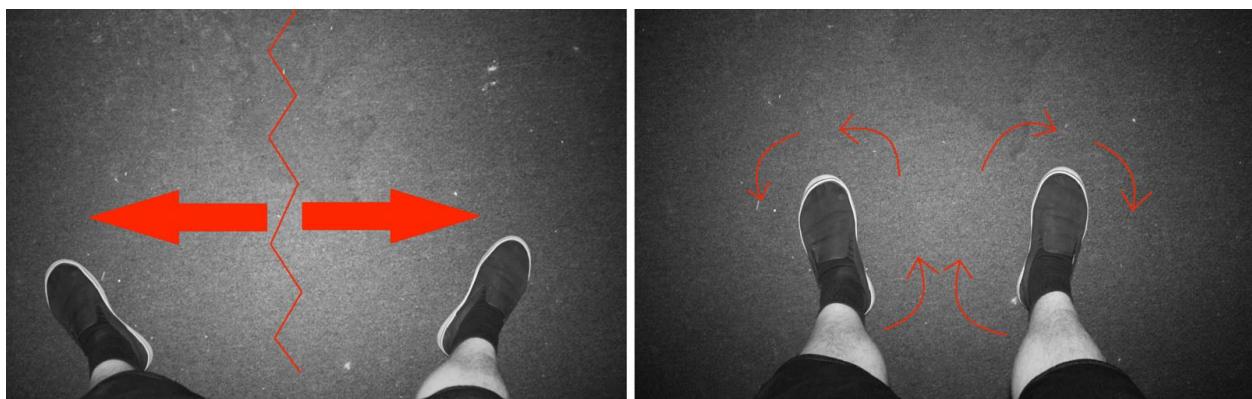
intra-abdominal pressure and brace your torso. There's only one thing left to do: *get even tighter.*

You want to create as much tension throughout your entire body as possible so that you'll be in utmost control of the bar.

That starts at the floor. You want to make sure you have three solid points of contact with the ground – your big toe, your pinky toe, and your heel – with your weight evenly distributed across all three points. This will help ensure you keep your balance, and it will keep your center of mass over mid-foot. I got this from [Quinn Henoch](#).

Next, to create tension in your hips, try one of two cues:

1. "Screw your feet into the floor." With your feet firmly planted, attempt to externally rotate your hips, like you're trying to point your heels toward each other, and your toes toward opposite walls. You may feel the outside of your foot pressing firmly against the wall of your shoe. This tends to be most effective for narrow or moderate stance squatters with their feet pointing further forward (up to about 20 degrees pointing out).
2. "Spread the floor." Imagine a fault line opened up between your feet, and you're trying to drive your feet apart to rip the crust of the earth in half. This tends to be the most effective for wider stance squatters who point their toes out farther.



Finally, you should also create tension in your upper back. This is partially accomplished via bar placement, elbow position, and grip width (a lower bar position, elbows under the bar in the back squat, and a closer grip naturally help you get your upper back tighter). To create even more tension in the back squat, try to bend the bar across your shoulders, like you're trying to fold it in half. In the front squat, drive your elbows as high as possible.

Setup Checklist:

1. Pick your bar position based on personal preference and your training goals (more on choosing a squat for your goals later).
2. Grip the bar as close as you comfortably can. If you're getting wrist, elbow, or shoulder discomfort, widen your hands out a bit or experiment with other ways to grip the bar (not wrapping your thumb around the bar for the back squat, and either crossing your arms or using straps for the front squat).
3. Drive your elbows under the bar for the high bar squat and for the low bar squat if your rear delts are big enough to easily create a stable shelf for the bar. Drive your elbows behind the bar if you need a little extra help tensing your rear delts enough. For the front squat, drive your elbows as high as possible.
4. Walk the bar out, expending as little energy as possible.
5. Get in your preferred stance width, and point your toes out to the appropriate degree (based on stance width, hip abduction, and knee tracking).
6. Take a deep, diaphragmatic breath (stomach expanding, not shoulders rising). Brace like you're going to take a punch to the stomach if you're squatting without a belt, and push your stomach and obliques against your belt if you're squatting belted.
7. Create total body tension from the ground up by finding and maintaining three points of contact with your feet, screwing your feet into the ground or trying to

spread the floor, and trying to bend the bar across your back if you're back squatting.

The Descent

Once your setup is squared away, it's time to squat!

Cuing the Descent

There are two basic ways to cue the descent: "sit down" and "sit back."

When you "sit down," you break at the knee and hip simultaneously, and try to drop your butt directly between your heels, keeping your torso as upright as possible.



When you "sit back," you break at the hip first and push your butt back, as if you were trying to sit into a chair behind you, purposefully allowing your torso to incline quite a bit.



There are advantages and disadvantages to each technique.

Sitting down generally allows you to squat deeper. Reaching full hip flexion is generally what limits depth in the squat, and since you're emphasizing hip flexion throughout the descent when sitting back, your bottom position will be a bit higher. In most contexts, a

longer range of motion means a superior training effect, so this is an advantage of sitting down, at least for day-to-day training purposes.

However, sitting down can be difficult for people with limited ankle range of motion. Since you're breaking at both the knee and the hip at the start of the lift, focusing on sitting down generally means more forward knee travel. If your ankles are too tight for your knees to keep going forward, that will push you back toward a "sitting back" position anyways, so many people with limited ankle range of motion simply feel more comfortable sitting back from the squat.

On the flip side, limiting your range of motion can be an *advantage* of sitting back. This is especially true for powerlifters who squat with a wider stance. On the platform, you don't have to squat low enough to bounce your butt off your ankles; you just have to break parallel. By sitting back and naturally having a bottom position a little below parallel instead of *way* below parallel, you're training a skill that can pay off in a competition.

A disadvantage of sitting back is that you won't go through as much knee flexion, so your squat likely won't be optimal for quad growth. This certainly doesn't matter in the short term when training for a competition, but it can limit you in the long run. 9 times out of 10, when I see a lifter with a great deadlift but a subpar squat, they have chicken legs, and their squat improves dramatically when they either do dedicated quad work or alter their technique to sit down into the squat and train their quads through a longer range of motion.

In the end, there aren't *major* differences between the two techniques. Research has shown that almost every relevant training variable and performance parameter (force, power output, muscle activation, etc.) is very similar [when comparing the two styles](#). The advantages and disadvantages of each technique are pretty small, so play around with both styles and see which one feels the strongest and most comfortable for you.

Speed of Descent

The next key factor is speed of descent.

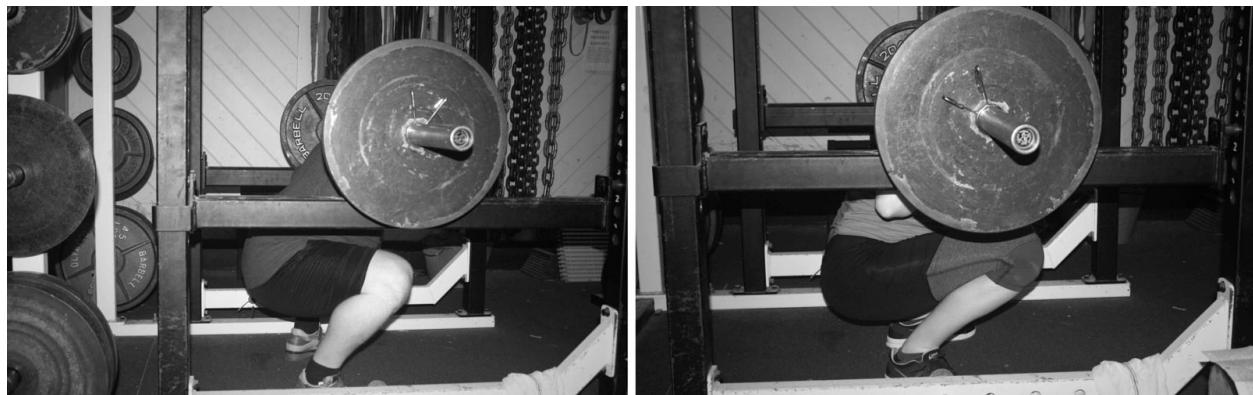
In general, your best bet is to descend as fast as possible *while remaining in complete control of the bar*.

A faster descent can help you get a little more "bounce" out of the bottom of the squat via the stretch reflex (when your muscles stretch quickly, they naturally contract with a bit more force for a moment when you reverse the movement), but a little extra pop isn't very helpful if you're loose and out of control when you hit the hole.

Depth

The final issue for the descent is ... when do you stop descending?

My simple answer: At the bottom. As low as your body will let you go. However, be aware that there's some variability in the depth people can achieve. Compare my rock-bottom position to my wife Lyndsey's.



I'm man enough to admit that I have depth envy.

Some people are concerned that deep squats will injure their knees or their back, so they squat high and cut their squat off as soon as their torso starts inclining forward ever so slightly. However, [the most thorough review of the scientific literature](#) found that deep squats posed no serious risks to the knees or spine. The loads on your knees and spine can certainly get very high with heavy, deep squats, but your body isn't fragile. Your tendons, ligaments, and spinal discs are primarily made of collagen: a tissue which

borders on ludicrously strong and durable. The demands on those tissues in a deep squat are well below the maximum that those tissues can withstand (assuming you don't have pre-existing knee or spine issues), *and* they remodel, grow, and get stronger in response to training, just like your muscles do (albeit at a slower pace).

Deep squats help you gain more strength and muscle than shallow squats, and they transfer better to most athletic endeavors (even vertical jumping, which actually mimics the half squat moreso than the deep squat).

If you're going to squat deep, then you may as well go until you bottom out. Not only do you get the benefits of increased range of motion, but *most* people find they can actually lift more weight.

Most people's sticking point in the squat (the point where the bar slows down dramatically, and the point where most people miss a squat that's too heavy) is a little bit above parallel. If you're squatting at least to parallel, the hardest point of the lift won't be your bottom position. It will be midway up, so you aren't making the lift any harder by sinking a couple of inches deeper.

When you squat until your hips stop you or until your hamstrings bounce off your calves, you'll get that bounce out of the hole that I mentioned before, which will help you in reversing the load so you'll have more momentum built up when you reach the sticking point. Most people find that if they bottom out 2 inches below parallel, it's a lot easier to complete the lift if they go 2 inches below parallel rather than cutting the squat right at parallel.

When you cut a squat higher than your natural bottom position, assuming you're still squatting to some position below your sticking point, you have to reverse the weight purely with active muscular effort instead of also getting a boost from your stretch reflex and the passive contractile properties of your muscles that kick in as they stretch. The advantage you gain from decreasing your range of motion is generally outweighed by the additional effort it takes to reverse the load without the aid of the bounce.

On top of the advantage you get from the bounce, there's an additional advantage to a higher bottom position: you're catching the bounce closer to your sticking point. Your sticking point is going to come at the same point in the lift (a bit above parallel) no matter how deep you go, so if you can catch the bounce just below parallel, you can ride it through the start of the ascent and still have more momentum left when you reach the sticking point.

If you're a powerlifter, there are some tweaks you can try that will let you take advantage of that bounce while being able to *naturally* have a higher bottom position: below parallel, but not deeper than is necessary for a competition.

1. As mentioned previously, if you can get really deep when sitting down into the squat, try sitting back instead. You'll reach full hip flexion higher, and naturally limit your range of motion a bit.
2. Try widening your stance out a bit more. The wider your stance gets, the higher your bottom position will get. Find the stance width that still lets you break parallel, but that doesn't let you go much past parallel.
3. Intentionally arch your low back harder. This will put your pelvis in anterior tilt, so you'll already be starting the lift in a bit more hip flexion.
4. If you generally high bar squat, give the low bar squat a try. Since the bar is lower on your back, you'll naturally have to lean farther forward to keep your center of mass over mid-foot. Like the other three tips, this will let you reach full hip flexion at a slightly higher depth.

If you try these tips and they don't click for you, that's perfectly fine! The advantage you get from being able to bottom out while still cutting your squat a little higher is a small one in the first place – just look at weightlifters who still squat a ton while going *super* deep. However, these are all tips worth experimenting with.

The Ascent

Now you've squatted down with a bunch of weight on your back. Time for the hard part: actually standing back up with it!

The ascent revolves around the single most crucial point in the lift: the sticking point.

Most people's sticking point is anywhere from 1-6 inches above parallel. The exact joint angles vary person to person, but it occurs almost universally in the middle of the lift.

Very few people get buried in the hole and don't even start coming up, and very few people miss once they break through the sticking point (unless they just lose their balance).

Your goal when you start driving out of the hole is to put yourself in a good position when you reach your sticking point, and your goal through the sticking point is just to grind through as efficiently as possible.

Initiating

With that in mind, when you start driving out of the bottom of a squat, you should initiate the ascent by driving your traps back into the bar aggressively while driving your feet through the floor. The #1 thing you want to avoid is getting caved forward and reaching the sticking point in a good-morning position. Since the bar is trying to crush you forward (imposing a spinal flexion and hip flexion moment), driving your traps back into the bar will counter that tendency.

For most people, your degree of forward lean at the bottom of the squat should be maintained until you reach the sticking point. Getting tilted farther forward with your hips drifting back takes your legs out of the movement to some degree, forcing you to fight through the sticking point primarily with your hip extensors and back.

The exceptions to this rule are people who squat *super* deep, and who can achieve a *super* upright bottom position. Your torso *will* incline forward a bit as you start driving out of the hole with this technique.



Notice how my back angle is the same in both pictures, while Lyndsey's torso is more upright in her rock bottom position, inclining a bit as she starts the ascent.

The Sticking Point

Once you reach the sticking point, your goal should be to make it through as efficiently as possible.

The biggest mistake people make at this point in the lift is panicking and rushing themselves. When this happens, they'll let their hips keep rising without the bar moving very much. The net effect is that, even if they made it to the sticking point in a good position, they're putting themselves in a less mechanically advantageous position, so they'll have to finish the lift as a good morning (if they finish it at all).

The better strategy is to continue driving your traps back into the bar aggressively, while simultaneously trying to drive your hips under the bar. Your knees will probably shift forward as well.



Drive your traps back into the bar and drive your hips under the bar to get through the sticking point.

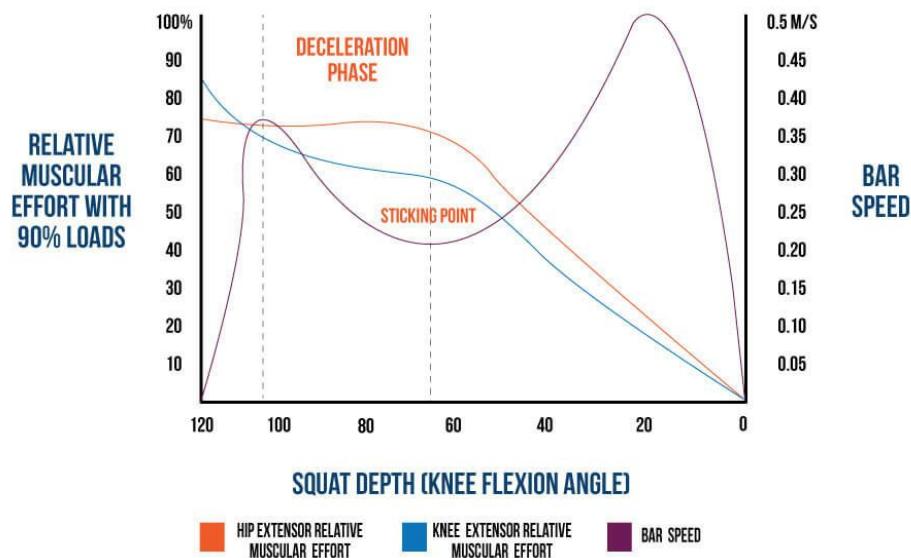
This feels almost like locking out a deadlift. In a deadlift, when the bar passes the knee, people are cued "shoulders back" and "hips forward" to keep their hips from shooting up higher and to make the lockout much smoother and more efficient. Those are precisely the same cues you should use to get through the sticking point of a squat.

To understand this cue, we need to look into the demands imposed by the squat.

Two studies by Bryanton ([one](#), [two](#)) examined the knee and hip extensor demands in the squat. They both looked at *relative muscular effort*, which is essentially the ratio between the knee and hip flexor moments imposed by the squat and the knee and hip extensor moments you're capable of producing at each joint angle. A large value means you're near the limits of your strength, and a small value means that the demands of the lift at that joint angle are very low. The image below overlays the data from those two

studies with data from [McLaughlin](#) on bar speed for world-class powerlifters lifting maximal loads.

KNEE AND HIP EXTENSION DEMANDS IN THE SQUAT



Though there's some variability, the sticking point tends to occur at around 70 degrees of knee flexion, with the bar decelerating (indicating high demands) until that point after an initial rapid acceleration. Through that part of the movement, relative muscular effort of the hip extensors is considerably higher than relative muscular effort of the quads. That means that when you miss, it's very likely that your hips weren't strong enough to break through the sticking point, and very unlikely that it was your quads that weren't strong enough to break through.

By trying to drive your hips back under the bar, you *decrease* the demands on your hip extensors, which are near their limit, and *increase* the demands on your quads, which can handle more of the load. This ensures that the load remains evenly distributed between the knees and hips to make the lift as efficient as possible.

One final point: *EXPLODE*. Lift every rep as fast as you can while still maintaining proper technique. Squats are hard, so many lifters simply put as little effort into each lift as possible. However, you'll [gain strength much faster](#) if you make a point of lifting each rep as explosively as you can, from the first rep of each set to the last.

Diagnosing Weaknesses

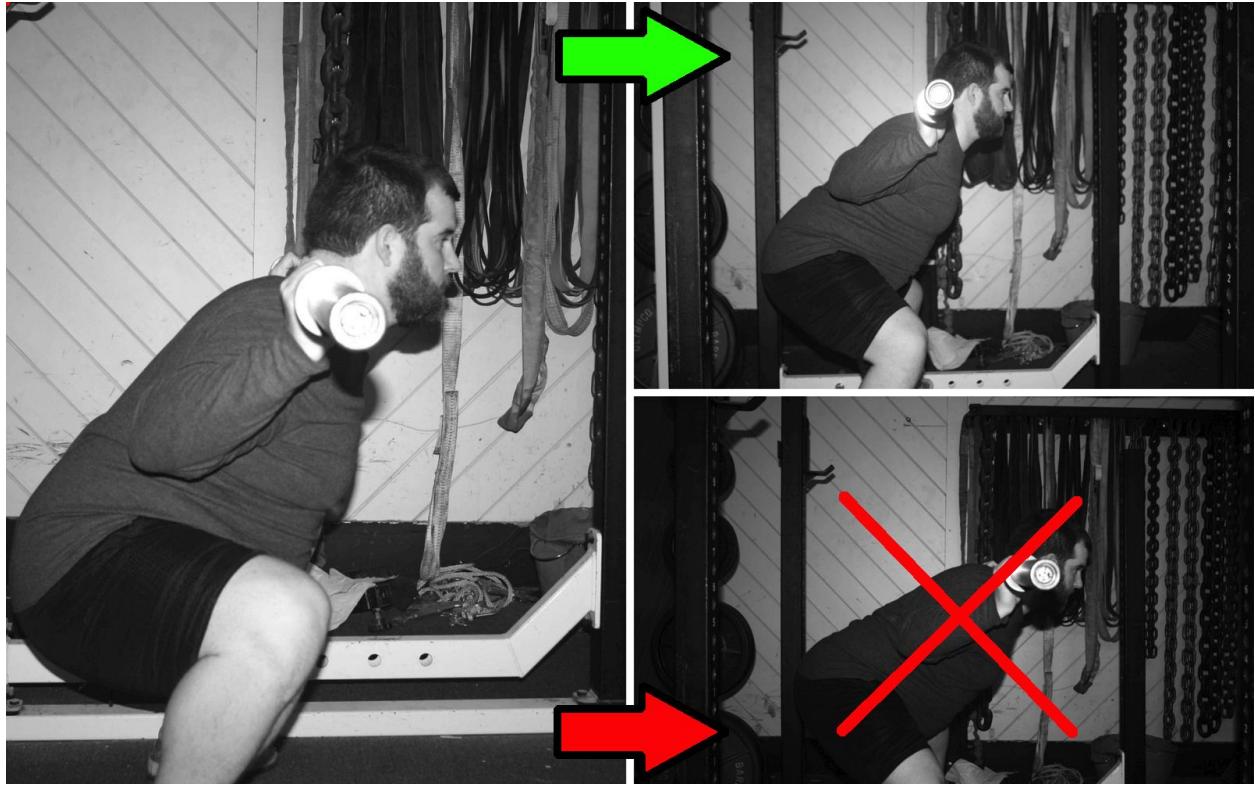
Now that you understand the basic demands of the squat, it shouldn't be too hard to figure out your weaknesses to improve your squat.

1) Quads

Remember, the demands on your quads are at their highest point at the very bottom of the squat.

If knee extension demands exceed your quads' capacity, they have a "safety valve" – your hips. Your knees kick back (shortening the knee extension moment arm and decreasing knee extension demands), your hips shift back, and your torso leans farther forward.

Instead of maintaining a constant back angle between the hole and the sticking point, you tilt farther forward, winding up in a "good morning squat" position because your quads weren't strong enough to pull their weight, so they shifted more of the load to the hips.



In the good morning squat, the knees and hips shift back, decreasing demands on the quads and increasing demands on the hip extensors, indicating a quad weakness – your body is naturally shifting the effort away from the quads toward the hips.

To correct a good morning squat, most people need dedicated quad work. It's been my experience that just doing more squats rarely corrects the problem. Front squats can help, since you *can't* shift the load excessively to your hips. If your torso starts inclining farther forward, the bar will just roll off your shoulders, so front squats force you to keep your quads heavily involved in the lift. Leg presses and machine hack squats are also great options. Finally, unilateral work like split squats, reverse lunges, and step-ups can help as well.

2) Core

When addressing the core, there could be two culprits: 1) back strength (thoracic spinal erectors in particular, especially for the front squat and high bar squat), and 2) the skill of bracing your torso to produce intra-abdominal pressure and support your spine.

The biggest tell-tale sign that your core is limiting you is a big discrepancy between your squat and deadlift. If your deadlift is more than 15-20% higher than you squat, it's likely a core issue.

Many people take for granted that there will be a big difference between your squat and deadlift, but when you really analyze the movements, you realize that you should actually expect to squat and deadlift similar weights.

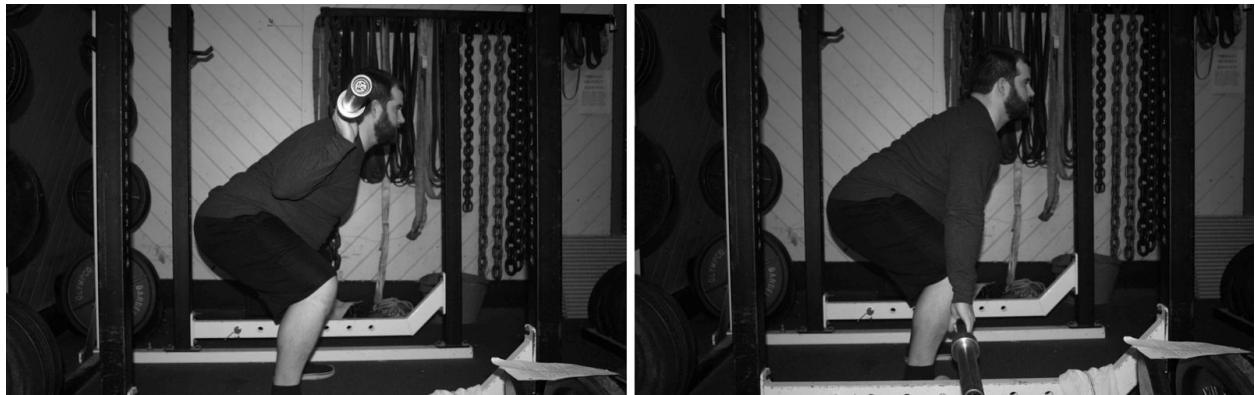
Deadlifts have two big advantages: the range of motion is shorter, and they allow for a little more form breakdown than squats do (if your spine flexes in the deadlift, you can often finish the lift. When it flexes much in the squat, you're usually dead in the water).

However, with squats:

1. Your sticking point occurs *above* the starting position in the deadlift. Remember, you don't miss a weight because you're too weak through the whole range of motion. You miss a lift because you were too weak through your very weakest point in the movement. Even if you wind up in a suboptimal good-morning squat position, you're essentially in the same position you'd be in a deadlift with the bar a couple of inches below your knee. Just simply looking at knee, hip, and spinal extension demands, if you can finish a deadlift from that position, you should be able to finish a squat from that position with the same weight.
2. In a squat, your knees can move freely. Your knees can track farther forward throughout the lift to keep the load distributed more evenly between your quads and hip extensors, and if you get stuck, your knees can shift forward along with your hips to efficiently make it through the sticking point. You don't have that same luxury with the deadlift. If your knees shift forward, they'll push the bar forward as well, throwing you off balance and ensuring you can't finish the lift.
3. When you reach the sticking point of the squat, the bar is already moving. You have some momentum built up when you reach your sticking point. Compare that to the deadlift, where you're pulling the bar from a motionless position on

the ground. Getting the bar moving in the deadlift is the hardest part for many people, but when you're in the point of your squat that corresponds with the start of your deadlift, you've already got some momentum on your side.

4. Finally, when you break through the sticking point of a squat, the lift is essentially finished. Barring some strange accident such as losing your balance, there's no way you won't finish a squat after you get past the sticking point. In the deadlift, however, many people still miss at knee height or lockout.



The sticking point in the squat vs. the equivalent position in the deadlift. If you can finish the deadlift with a given load, your quads and hip extensors are strong enough to finish a squat with the same load.

The biggest factor that explains why most people can deadlift more than they squat is that people naturally brace more effectively for the deadlift. You've been picking stuff up off the ground for your entire life, including when you were very young with the ability to master motor skills faster and more effectively. You were probably squatting from a young age as well, but you weren't squatting with a heavy load across your shoulders, so when you start squatting with a bar, the bracing pattern is totally foreign to you.

In other words, your squat and deadlift numbers should be pretty similar. If they aren't, the most likely explanation for the difference is suboptimal core bracing patterns.

If this sounds like your problem, I addressed it in much more depth in [this article](#), along with exercises specific to the squat that you can do to work on improving your bracing.

3) Hips

By process of elimination, if you're not limited by your quads or your core, there's only one place left to look: your hip extensors.

This is a good thing. This is what "should" be your limiting factor if you brace well and you have strong quads.

The best exercise to improve your hip extensors' strength for squatting: more squats!

If you want to add some other exercises into the mix, however, good mornings, stiff leg deadlifts, hip thrusts, glute ham raises, hyperextensions, and [banded kneeling squats](#) are all great options.

Common Questions and Issues

Are squats safe?

There is the potential for injury with every exercise. However, on a risk scale from 1 to "snap city," *properly performed* squats are a 1.

The reason I say "properly performed" is that things like spinal flexion or excessive knee caving can make squats more dangerous.

However, if you don't have issues with your spine rounding or your knees caving in, squats carry a [very, very low injury risk](#) if you don't have pre-existing joint issues.

Again, healthy spinal discs and healthy connective tissue in your knees can handle loads way higher than you'll face in the squat. Those same tissues can also remodel and get stronger in response to squatting, further decreasing your injury risk both when squatting and when playing other sports.

What do I do about buttwink?

Buttwink is the nemesis of many. If you aren't aware, buttwink occurs when the lumbar spine rounds and the pelvis tilts posteriorly a bit at the bottom of the squat.



Neutral pelvic and lumbar positioning on the left, and buttwink on the right.

The first thing you should figure out: Is it buttwink, or is it simply your spine going back to neutral? If you squat with a hard arch, your lumbar spine is hyperextended and your pelvis is anteriorly tilted throughout the descent. When you reach the bottom of the squat, what looks like buttwink at first glance may simply be your lumbar spine and pelvis moving from hyperextension and anterior tilt back toward neutral. Get a video of your squat from the side, and see whether your back looks like it's going from a big arch to a smaller arch, or whether it's going from a slight arch to being rounded.

If it *is* buttwink, the first thing you should do is test whether you *can* actually squat to depth without buttwink. Some people's hip anatomy simply won't allow them to. You can use [this assessment](#) to find out.

The one little thing I'd change about the assessment the way it's presented in this video: drop your chest a little closer to the floor so that the assessment more closely mimics a horizontal squat.

If you pass this test and you *can* reach the required level of hip flexion without buttwink (your hip crease can get behind your knee without buttwink), then it's not a mobility issue – it's a control issue.

There are two strategies you can use to try to address this problem:

Strategy 1

Remember the difference between squats and deadlifts: most people naturally brace better for anteriorly loaded movements.

Start with a goblet squat. See if you can squat without buttwink when goblet squatting. If you can, add load each session until it simply becomes challenging to get the dumbbell or kettlebell in position to keep goblet squatting. After that, move on to front squats, which are still anteriorly loaded, but more challenging than goblet squats. You *should* be able to front squat without buttwink after really mastering the goblet squat. After 4-6 weeks of front squats, move on to high bar back squats, which you should be able to control well at this point. If that goes well, then give low bar back squats a shot (if you want to low bar back squat).



Strategy 2

Use progressive range of motion. See how deep you can squat without your butt starting to tuck under. Set the safety pins to that height, and squat to the pins, starting with a slightly lighter load than you were squatting before (since it's a little hard to squat to pins). Squat down to the pins, let the bar rest on them for a second (don't bounce the bar off the pins), and come up. Every week or two, lower the pins one position. Keep going until you're squatting to depth.

Combine both of these approaches with planks and side planks before each set of squats. The reason you should include them is explained [here](#).

Further reading on this topic.

Why do people's squat forms vary so much?

Many people squat for specific goals that require (or at least benefit more from) a particular style of squat. For example, powerlifters often try to squat in a manner that will allow them to lift the most weight possible through the minimum range of motion required for competition. Weightlifters, on the other hand, try to squat as deep and upright as possible for better carryover to the clean and snatch.

On top of these practical reasons are anatomical reasons. There are a multitude of differences in hip anatomy that can make people squat differently, including different hip socket depths, different angles of inclination of the neck of the femur, different degrees of rotation of the femoral neck about the shaft of the femur, and different positions for the hip socket on the pelvis. Throw in different femur lengths, varying degrees of ankle mobility, varying attachment points for the muscles around the hip, and different levels of strength in the prime movers, and you have a lot of factors that can influence how someone will squat best.

More reading [here](#), [here](#), [here](#), [here](#), and [here](#).

Can everyone squat ass to grass?

No. All of those different anatomical factors determine how deeply someone can squat. Many people can squat ass to grass, but many people can't, no matter how much they work at it.

Should I have a vertical bar path?

A lot of people have the idea that if you don't have a perfectly vertical bar path, your squat is inefficient. They treat it as an immutable law of good squatting.

However, this simply isn't true. With very heavy loads (2x your bodyweight or more) your bar path should be very close to vertical, but you shouldn't expect it to be with lighter loads.

Why?

The simple answer is this: your ass isn't weightless.

The slightly more complex answer:

If you assume that the barbell itself is the center of mass of the system, then yes, you should expect the bar path to be pretty darn vertical, with the bar always staying over the middle of your foot.

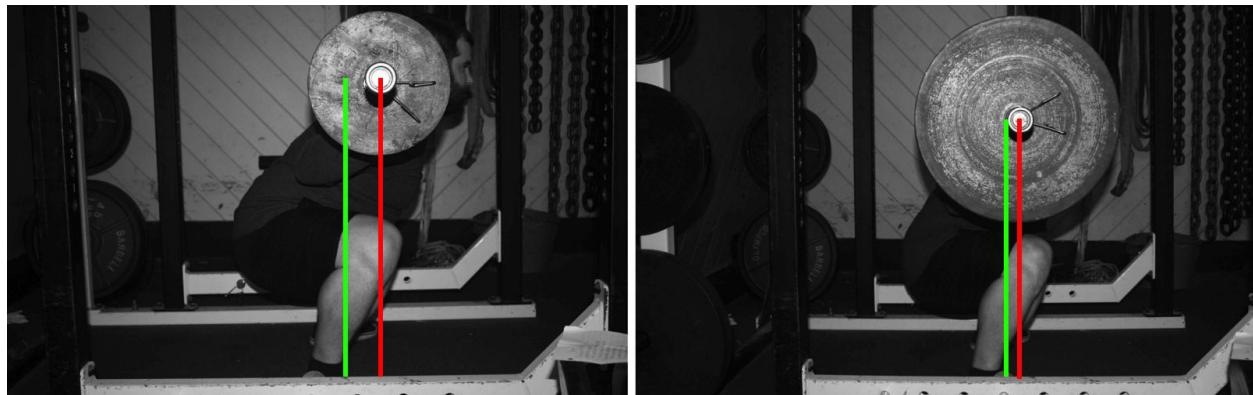
However, the barbell itself is not the center of mass of the system. You can't discount the mass of your body segments. Almost all of your torso will be behind mid-foot, and most of your femur will be behind mid-foot, while your arms will be roughly over mid-foot, and most of your lower legs will be mostly over or slightly in front of mid-foot. Taking all of those segments into account, the center of mass for your body will almost certainly be behind mid-foot for most of the lift.

I'll spare you all the math, but essentially bar path depends on the weight of the bar compared to the weight of your body. If you're 200lbs and you're squatting 200lbs, and you want the center of pressure to remain over mid-foot, then the bar is going to need to shift forward to the same degree as the center of mass of your body shifts back. If you're 200lbs and you're squatting 600lbs, then the bar will only need to shift forward 1/3 as far as the center of mass of your body shifts back (and at that point, the bar path will basically be vertical).

Yes, you want the center of pressure to stay over the middle of your foot.

Yes, you want the center of mass for the system to stay over the middle of your foot.

No, you shouldn't expect the bar to stay over the middle of your foot and move in a perfectly vertical line unless you're squatting a ton of weight.



Forward bar travel with 95lbs vs. 315lbs. In both pictures, the center of pressure is over midfoot, but the bar drifts farther forward with the lighter load due to the mass of my body behind the bar.

[This site](#) illustrates this point really well. It's based on an incredibly accurate and thorough biomechanical model (I know it's accurate, because I helped the programmer implement it. It's based on the methods for performing a quasistatic analysis in three dimensions as described in *Biomechanics and Motor Control of Human Movement* by Winter, which is probably the best biomechanics textbook out there).

Is a wide stance squat easier?

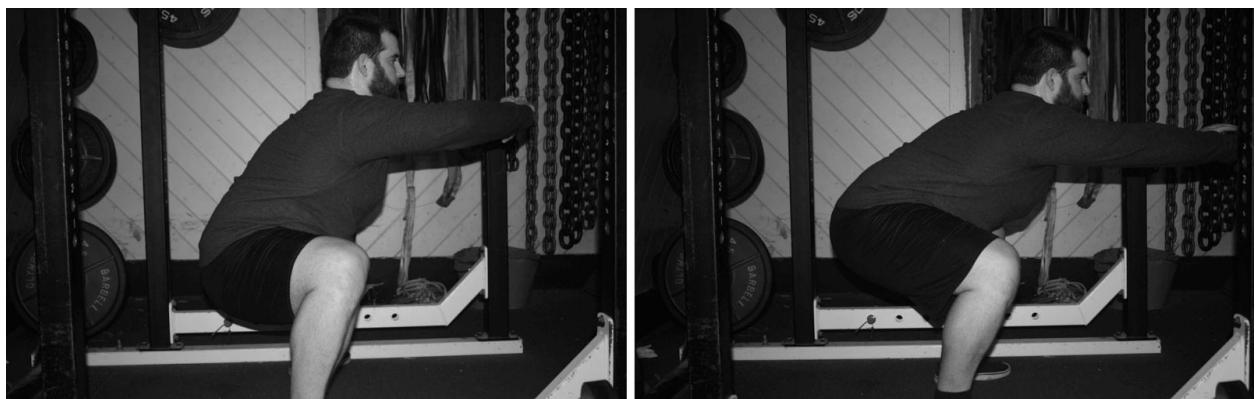
For starters, it's not necessarily easier for all people due to differences in hip anatomy and muscle attachment points. If you have hip impingement issues when squatting with a wide stance, for example, it doesn't matter what the external joint moments are. You still won't be able to squat very much. Additionally, your muscles' attachment points may be favorable for producing a lot of hip extension torque in dead ahead hip flexion, and not nearly as much with a fair amount of hip abduction.

Also remember, knee and hip extensor moments are calculated in the sagittal plane relative to the femur, not the sagittal plane relative to the torso, so the fact that the femur is "shorter" front to back when looking from the side is irrelevant. When

calculating joint moments more appropriately in three dimensions, stance width doesn't change the summed knee and hip extensor demands.

Wide stance squats may still have some slight advantages, though.

Even though your femur being "shorter" front-to-back doesn't affect total demands at the knee or hip, that *can* allow you to stay slightly more upright throughout the lift, making the lift a little easier on your spinal erectors.



Notice the difference in back angle and front-to-back length of the femur. Also, now you know why I squat with a wider stance and more hip abduction – the picture on the right is as low as I can get with a close stance and my knees tracking roughly straight ahead. Why? Different hip anatomies require different squat styles.

The second advantage is that a wider stance gets your adductors into the lift more, specifically your adductor magnus. Based on brand new modeling research (so new that I unfortunately can't share yet at the request of the authors since it's still in peer review; I'll add it once it's accepted), the adductor magnus likely produces a larger hip extensor moment than your hamstrings and glutes *combined* at the bottom of the squat. I know that I personally feel more "pop" from my hips when I reverse a squat with a wide stance, and I also get horrendous adductor soreness if I squat wide after squatting narrow for a while. I strongly believe those two things are related.

The final advantage, as previously discussed, is that a wider stance squat allows you to bottom out and catch your bounce closer to parallel, instead of bottoming out deeper than you need to if you're a powerlifter.

Again, [this site](#) does a great job of illustrating the (very small) effects of stance width on the demands in the squat.

Where should I focus my eyes?

People obsess about head position to a potentially unhealthy degree. They opine that looking up will strain your neck or damage your cervical spine over time, and they posit that looking down will cause you to cave forward. I also see people talk about a Russian study that supposedly showed that looking up increased activation of the spinal erectors and hip extensors, while looking down increased activation of the quads. I've looked for this study, and I've asked multiple people who've referenced it to send me a copy. So far I've come up empty, and I'm starting to think it simply doesn't exist.

After 10 years in the sport, I've literally never seen a neck injury from squatting, and I've seen *many* successful squatters look up, down, or straight ahead.

Here's the important part: Find one point to focus on, whether that be 10 feet in front of you on the floor, somewhere on the wall, or at the juncture of the wall and the ceiling. Focus intensely on that one point throughout the lift. This will help you keep your balance and avoid being distracted by what's going on around you.

What should I do about elbow pain?

First things first, if the simple steps below don't help, go see a physical therapist.

Most elbow pain from squatting is a result of poor thoracic spine extension and poor shoulder external rotation, meaning you have problems getting your hands behind the bar in the first place, putting a lot of strain on the medial side of your elbow. This can be

compounded by having a poor shelf to rest the bar on so your arms end up bearing more of the load instead of letting your back handle it.

You can first try adjusting your grip – taking a slightly wider grip and not wrapping your thumb around the bar, as addressed above. The drills in [this article](#) will help you improve your thoracic mobility. Finally, if all else fails, you can just switch to high bar squatting. *Almost* all instances of elbow pain in the squat I've seen come from low bar squatters. At the very least, you can switch to high bar while you work on improving your mobility until you can comfortably squat low bar again.

How should I squat if I want to build my quads?

In general, longer ranges of motion mean more hypertrophy. Your knees will generally go through more flexion front squatting or high bar squatting than they will low bar squatting, even if you use the same cues, simply because your torso is slightly more inclined with the low bar squat, meaning your hips reach full range of motion and cut your depth off a bit higher.

When comparing the high bar squat and front squat, three studies have measured muscle activation ([one](#), [two](#), [three](#)). Two found no differences, and one found slightly (and I do mean slightly) higher muscle activation in the quads with front squats.

Any type of squat will build your quads, but high bar squats and front squats taken as deep as possible, sitting down into the lift instead of sitting back into the lift, will probably build your quads the best.

Can I stick solely with squats to maximize leg development?

While squats should probably be at the center of your lower body training, squatting probably won't maximize leg development by itself.

In particular, other lower body exercises give you higher levels of rectus femoris and hamstrings activation. In all likelihood, this means that using a wider array of exercises will be necessary for maximizing leg growth. This isn't overly surprising, since the

nervous system generally prioritizes recruitment of single-joint muscles over the recruitment multi-joint muscles in compound exercises (there's not a ton of research on that particular topic yet, but that's the direction it's leaning).

To maximize rectus femoris development, pure knee extension exercises (like leg extensions) will help, and to maximize hamstrings development, purer hip extension (like RDLs, good mornings, and back raises) and knee flexion (like leg curls and glute ham raises) will help.

In addition, there's a growing body of evidence that certain exercises grow certain regions of a particular muscle to a greater or lesser degree, so including different variations of squats along with other compound lower body movements will probably help maximize quad development.

[This article](#) explores this topic in more depth (with sources), although this shouldn't come as much of a surprise. Bodybuilders who seek to maximize leg development have relied on a broader variety of exercises for a long, long time.

What should I do about knee or back pain?

First, make sure you don't have any major technique issues, such as your knees caving in, your heels coming off the ground, or your back rounding. If all of those things are squared away and you still have joint pain, see a physical therapist. That's their domain of expertise, not mine as a coach.

My knees are caving in. Is that bad? If so, how do I fix it?

It largely depends how much they're caving in. It's not uncommon to see the knees "tick" in slightly as you're coming up out of the hole. Many people, including a lot of high-level weightlifters, squat that way without issue. However, excessive knee caving should be avoided.

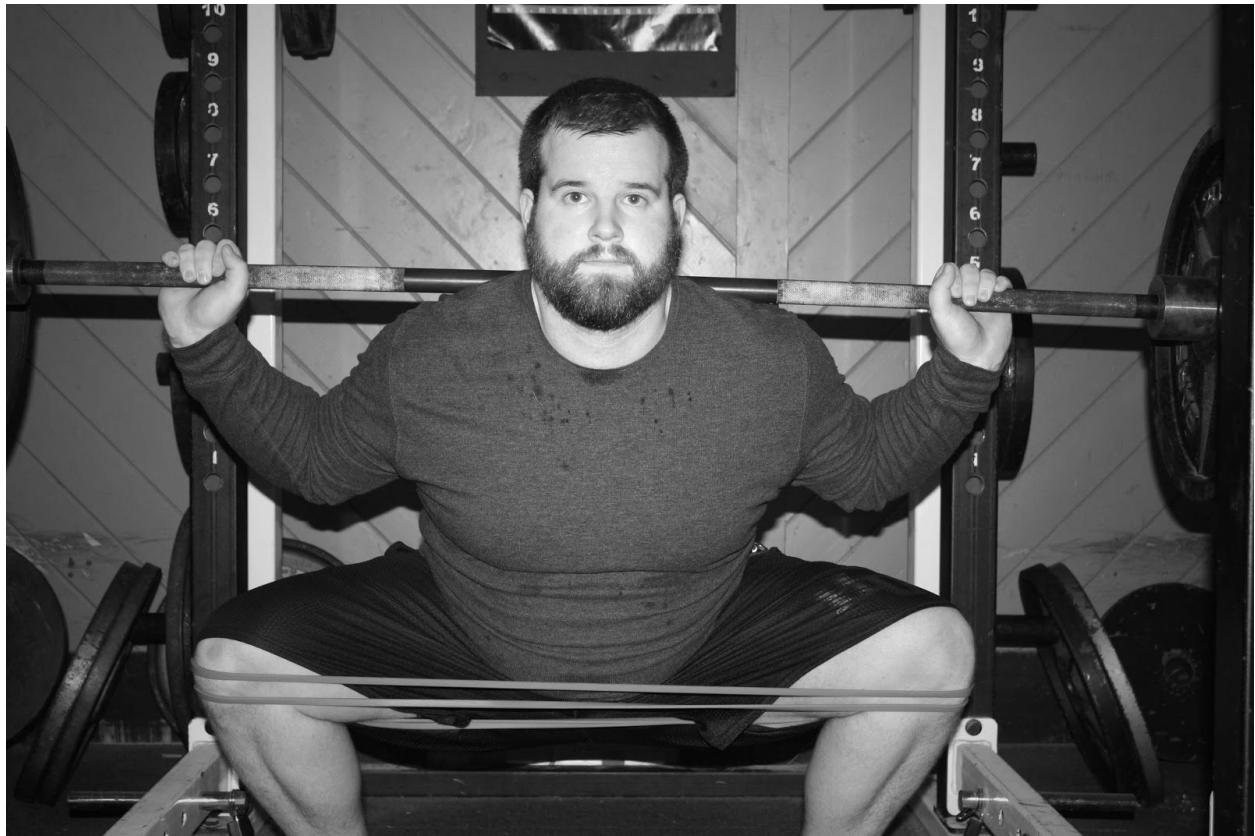


In the first picture, my knees are tracking directly over my toes. In the second, they "tick" in a bit, which generally isn't problematic. In the third picture, they're caving to a degree that's likely dangerous.

How do you know it's excessive? If it causes pain, it's excessive. If you video your squat from the front and your knees tick in noticeably more than the squatters who intentionally let their knees tick in, it's probably excessive.

There are three simple things you can try out to correct this issue.

1. Try bringing your stance in. For many people, their knees cave in because they're trying to squat wider than their hips will allow, and narrowing their stance fixes the issue immediately.
2. Try squatting with a band around your knees. This tactile cue will "remind" your hip abductors to push out against the band to keep your knees out. After squatting like this for a few weeks, the motor pattern should be ingrained well enough that you can squat without the band and your knees will "remember" to stay out without the tactile cue of the band. There's a picture of this below.
3. If neither of those things work, you can do dedicated abductor work to strengthen those muscles. My favorite exercise for this purpose is hip thrusts with a band around your knees. By combining active abduction with hip extension, this mimics what your hips do in the squat better than abductor isolation movements.



The bar is uncomfortable on my shoulders.

If you're doing a high bar back squat, move the bar a little lower. It's likely pressing against the spinous process of your C7 vertebra.

If you're doing a low bar squat, move the bar either a little higher or a little lower. It's likely pressing against the spine of your scapulae.

If you're doing front squats ... just suck it up or don't front squat. They're never comfortable until you eventually deaden the nerves surrounding your clavicles and AC joints.

The weight is shifting forward and I'm losing my balance.

Making sure you're driving your traps aggressively back into the bar can help with this. When you do that, you're simultaneously fighting to extend your hips and drive the bar *back*. If that doesn't work, [this little trick](#) can help a lot.

What should I do about tight ankles?

The first thing you should do is make sure your ankles are actually tight. There's a simple test for that:

Place your toe against a wall, and rock forward, keeping your heel on the ground. If your knee can touch the wall, back your foot up by about half an inch and repeat. Keep going until you can't get your knee to the wall without your heel coming off the ground.



In the first three pictures my knee is touching the wall with my heel on the ground. In the fourth, it's hard to see, but my knee hasn't quite made it to the wall, and my heel is starting to come off the ground.

If your toes are more than about 2 inches from the wall when you reach that point, you have enough ankle mobility. *Most* people who think they don't have enough ankle mobility pass this test just fine. (As a note, I got this test from Quinn Henoch.)

If it still *seems* like you don't have enough ankle mobility when you squat, even though you passed this test, you may simply have weak calves. The [same research](#) looking at relative muscular effort for the quads and hip extensors examined relative muscular effort for your calf muscles, and found that those demands can actually get quite high.

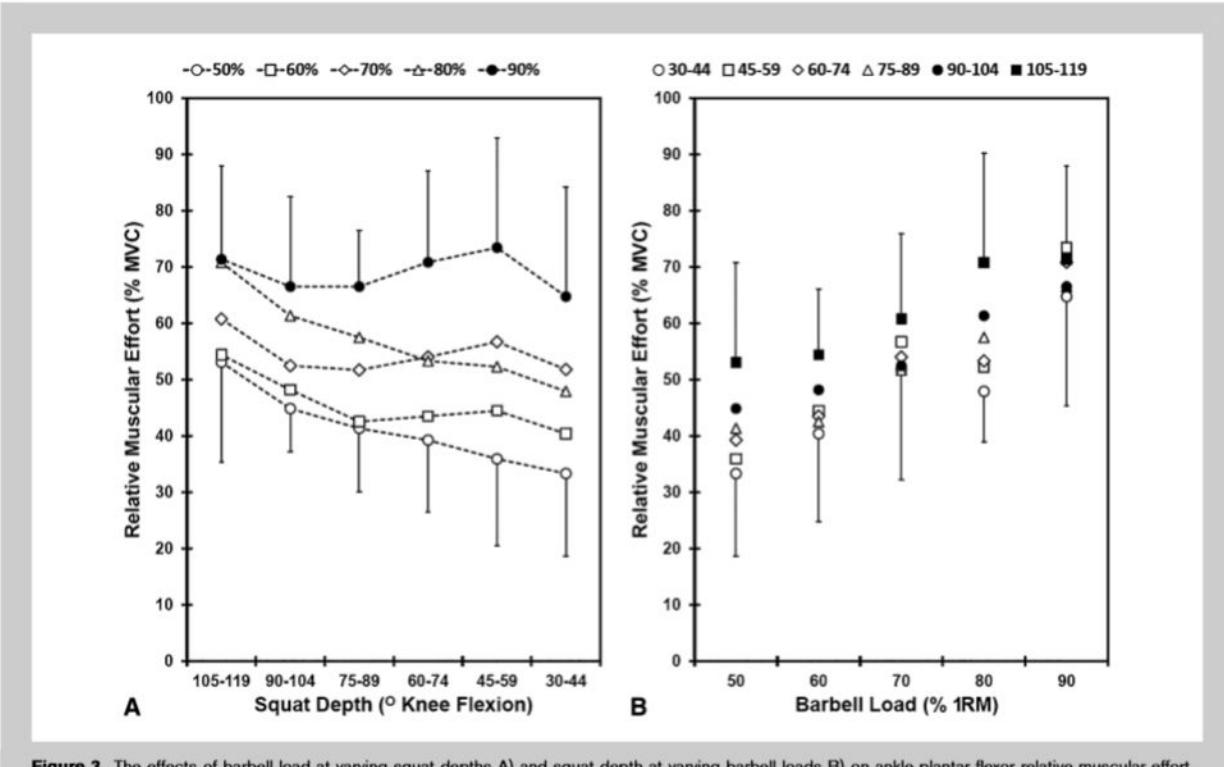


Figure 3. The effects of barbell load at varying squat depths A) and squat depth at varying barbell loads B) on ankle plantar flexor relative muscular effort.

It's entirely possible that your calves simply aren't strong enough to allow your knees to track farther forward, because as your knees track farther forward, plantar flexor demands increase (generally as your knees track farther forward, center of pressure on your foot shifts forward a bit as well).

How do you fix this? Calf training, of course.

What's much more likely, however, is that it's actually due to a quad strength issue. The further forward your knees track, the higher the demands on your quads are. As the weights increase, you'll naturally shift more and more of the load to your hips, meaning your knees don't track as far forward. This "looks" like poor ankle mobility.

If it's a strength issue, it's hard to tease out whether the culprit is your quads or your calves, because the end result is the same: either your knees won't track forward

because doing so would increase plantar flexor demands too much, or your knees won't track forward because doing so would increase knee extension demands too much.

If you have chicken legs, it's probably quads. If you haven't trained your calves in 3 years and you don't do anything "athletic" (sprint, jump, etc.) that would indirectly train your calves, then it's probably your calves. If you have chicken legs *and* you don't train your calves, then add in more quad work and some direct calf training. Simple.

If it is actually a mobility restriction, you can just get some weightlifting shoes with a raised heel. Problem solved.

How do I correct the weight shifting to one side?

The first question is whether you *need* to correct it. [Bilateral asymmetries are the norm](#) rather than the exception, and 9 times out of 10 they don't cause any problems.

If you think side-to-side imbalances are causing you issues, if you want to take the "better safe than sorry" approach, or if you just want to balance out your squat so it looks better (I'm not judging), check out the link above which looks at this issue in more depth and provides training advice about how to address it.

Do I have to squat below parallel?

No one's pointing a gun at your head and forcing you to squat below parallel. If you want to compete in powerlifting, you'd better figure out how to, though. Additionally, if you *can* squat below parallel, you'll probably get a better all-around training effect from squatting deep.

However, not everyone *can* squat below parallel. Most people can, but hip anatomy simply doesn't allow some people to squat below parallel safely.

Dr. Stu McGill, the foremost expert on spinal biomechanics, addressed this topic [in an interview with Bret Contreras](#). I think he explained it beautifully and candidly, so instead of trying to paraphrase it, here's his take on the matter in his own words:

“When you do a deep squat, there are several components that determine the amount of motion that they have. Of course, there is muscle tightness. But if you’re doing the squat then that’s overridden. That’s probably not gonna matter much. There’s the joint capsule, neural tensions, and for the clientele I see, people with disc bulges and traps in their back, that matters. The neural tension that they will feel through the piriformis area behind their hip and what not.

“But the most important matter on all of this is the depth of the hip socket. If people are looking up on the internet, depth of the hip socket and squat ability, they won’t find it. They have to go to the hip dysplasia literature. What they’ll find is that there are groups in the world with very shallow hip sockets and they have very high rates of hip dysplasia. The center of the world for hip dysplasia is Poland. They have very shallow anterior hip sockets and they can squat very deeply. The femur comes right up because there is no bone on bone contact there.

“It’s actually called the Dalmatian Hip, which originates on the Dalmatian coast of Croatia up through Bulgaria into Poland and into Western Russia, which is the Ukraine. Now I think I just named the countries that produce year after year, unbelievable Olympic lifters. They also have the highest rate of hip dysplasia. So again, it’s form and function – and form and function determines athletic ability. It determines where you become arthritic and all the rest. It was very interesting. I occasionally do legal cases as a spine knowledge source (I guess) and I worked on a couple of murder cases believe it or not, where they needed some spine expertise. And another one of the scientists was a professor of forensic anthropology. It was her who first showed me all of these different hip architectures and how they change throughout the world. So it helped her to identify bodies when the skin and the hair and other features were burned off, say. That’s the Dalmatian hip, which is ideally suited for deep squatting. Now you take the archetypical shallow socket hip and it’s a very deep hip socket and that’s a Celtic hip, prevalent in the Normandy area of France, Ireland, and Scotland.

“Now how many Olympic lifters come from those countries. Not very many. The reason is they have very deep hip sockets and when you measure the power production out of that hip architecture, you’ll find that they don’t have much power at the bottom of the squat pulling out of the hole to use an athletic term. But the top half of this squat is really powerful. So for throwing the caber and things like that, it’s a standing strength or a very shallow squat strength. That’s where the power is. Am I saying that all Scottish people have deep hip sockets and that all Polish have shallow? No I’m not. I’m just saying that’s the tendency from those genetic pools. Anyway, that’s a start to the discussion. And it’s not that I care where you’re from but what it motivates me to do is a hip exam. As you know, I have an assessment DVD where I show these techniques and then I can start answering the questions to guide athletes. Should they be squatting deep? Should they be concerned about butt-wink? Or should they avoid that because they’re stressing the anterior labrum of the hip. They are stressing their spines. Chances are that they are gonna survive a lot higher volume of training if they pull off blocks. So they only squat deep enough where they can save the labrum of their hip and save their spine. You know, say you’re an NFL lineman. Why do you need to deep squat if you’re an NFL lineman? Why not just squat as deep as you can to the point of where the pelvis starts to break away? Because that’s where the femur is collided up against the labrum of the hip anyway. Take all the stress out. You’re still gonna play offensive tackle in the NFL just as well. You’re still gonna get strong and better yet, you can now tolerate a higher volume of training because you’re removing that stress riser. That’s a key for a lot of people.”

Is it okay if my knees go past my toes?

For most people, yes.

More forward knee tracking may increase compressive and shear forces on the knee slightly. However, your tendons, ligaments, and menisci can easily tolerate the forces you place on them in a deep squat, and they will adapt to get stronger in response to

training. If you have healthy knees, letting your knees track past your toes isn't a concern.

However, if you have pre-existing knee pain, letting your knees track farther forward may possibly cause some issues. If you get knee pain when your knees track farther forward, but you don't when you sit back into the squat and don't let your knees track forward quite as far, then obviously you shouldn't let your knees track as far forward. Otherwise, it's fine.

Will squats make me better at other sports?

Unless you're already a very strong squatter, improving your squat will probably make you better at other sports.

Squat strength and power relative to body weight predict sprint performance, and increasing squat strength decreases sprint times. This is also true for jump height in most studies. ([one](#), [two](#), [three](#), [four](#), [five](#), [six](#), [seven](#))

When last I checked, running faster and jumping higher make you better at most sports.

There's almost certainly a point of diminishing returns, but aiming for a ~2x bodyweight full squat would be a good goal for most athletes who play sports that require a lot of running and jumping. They may be less beneficial for shuffleboard, however.

Bar Position

Now that most of the general information about the squat is out of the way, it's time to tackle a big topic that people seem to care deeply about: bar position.

Should you high bar squat, low bar squat, or front squat?

First, let's address the differences between the three:

1. Where the bar is resting (obviously).

2. Joint angles: Generally, you reach the highest degree of hip flexion in the low bar squat, a similar degree or slightly less in the high bar squat, and about 10 degrees less in the front squat. The opposite trend applies for knee angles: you can typically reach higher degrees of knee flexion in the front squat and high bar squat than in the low bar squat (again, a difference of roughly 10-15 degrees). These differences at the knee and hip are driven by differences in torso angle. To keep the center of mass over mid-foot, all other things being equal, your torso will be the most inclined when you're low bar squatting and the least inclined when front squatting, with high bar squats in the middle. Because of this, you hit full hip flexion sooner in the low bar squat, whereas you may not reach it at all in the front squat; since you reach full hip flexion earlier in the low bar squat, you generally don't attain quite as much knee flexion.
3. Of the three, people front squat the least by far. There tends to be a 15-20% difference between the front squat and the high bar squat. Additionally, for most people, there's a 5-10% gap between the high bar squat and the low bar squat.

First things first, let's try to figure out why most people can squat the most low bar.

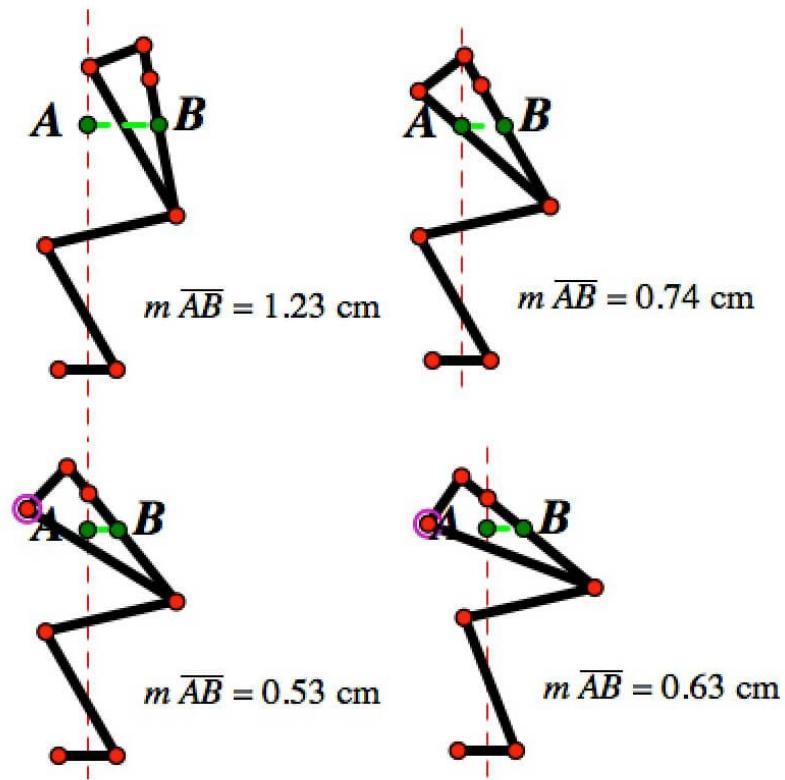
If you've been paying attention so far, one thing should be obvious: Factors from the waist down probably don't play the primary role. The sum of knee and hip extensor demands with any absolute load are identical through any given range of motion between all three bar positions (refer to the biomechanics section). Not only are total lower body extensor demands identical, but your [two-joint muscles](#) (your hamstrings and rectus femoris) work to distribute those demands efficiently between the knee and hip, regardless of how the squat looks (muscle activation is very similar between different styles squats for this reason).

Bottoming out slightly higher from hitting end-ROM hip flexion sooner plays a role, but that's certainly not a big enough difference to explain the entirety of the gap. Especially with the front squat, another obvious factor is that you can't "get into your hips" as well. Your maximum hip extensor strength is quite a bit higher than your maximum knee

extensor strength, so even if the summed knee and hip extensor demands are identical with any discrete load, you can't shift more and more of the demands to the hips as you add weight to the bar in the front squat because that would necessitate more forward lean; the bar would just roll off your shoulders. However, that still doesn't do anything to explain the gap between the high bar and low bar back squats.

There is one major factor that often goes overlooked, though: upper back strength.

I've thought for a while now that thoracic erector strength may be the primary (but not the only) reason most people squat more low bar than high bar. However, until now I'd just been too lazy to quantify the difference.



So what are you looking at here?

The segment lengths are based on average male proportions from [EXRX](#) (average female proportions are very similar, so that wouldn't change the numbers much). For

example, the torso is 30% of body height on average so it was 3cm, the thigh is 23.2% of body height so it was 2.32cm, etc.

The three red dots near the top of each figure represent each bar position (front squat, high bar, and low bar). The green point on the spine labeled "B" is approximately at the junction between the 9th and 10th thoracic vertebrae. The length of segment AB is the thoracic extension moment arm. The numbers themselves don't matter, just the relative size.

Top left is front squat, top right is high bar, bottom left is low bar assuming similar cuing as high bar, and bottom right is a more "hip dominant" low bar. All are from right around the sticking point.

The thoracic extension moment arm is WAY longer for the front squat than for either style of back squat: about 165% of high bar, 200% of the more hip-dominant low bar, and 235% of the less hip-dominant low bar.

Thoracic extension moment arm for high bar was ~115-140% longer than low bar. In other words, if you squatted the same weight high bar and low bar, the demands on your thoracic spinal erectors would be 15-40% greater for the high bar squat.

Since summed knee and hip extensor moments would be the same for any absolute load with all bar positions, this strongly supports the idea that thoracic extension strength may be one of the key reasons for the difference in performance between the front squat, high bar squat, and low bar squat. I don't think it's a coincidence that two of the only high bar squatters who compete at the international level in raw powerlifting – [Mike Hedlesky](#) and [Bryce Lewis](#) – are also phenomenal deadlifters.

So what do we do with these differences? How would this impact the training effect you'd get from one style of squat?

First off, let me acknowledge that research doesn't directly answer this question. In a general sense, there have been a lot of studies comparing a lot of different varieties of

squats, and most report very few differences (statistically or practically when looking at joint moments, muscle activation, kinetic data, etc. They'll all be linked below, if you want to check them out).

Here are two great examples.

This [Masters Thesis by Goodin](#) gives us the best look at performance-related variables comparing the high bar and low bar squat, working up from 20% to 90% loads. The high bar technique was purposefully "quad-dominant" and the low bar technique was purposefully "hip-dominant":

Figure 1 – Changes in Peak Force with Increasing Load

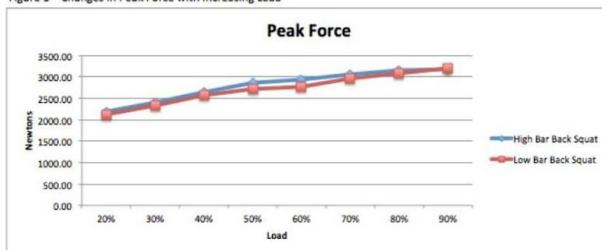


Figure 2 – Changes in Peak Power with Increasing Load

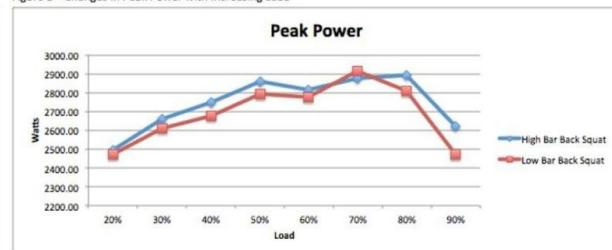


Figure 3 – Changes in Peak Velocity with Increasing Load

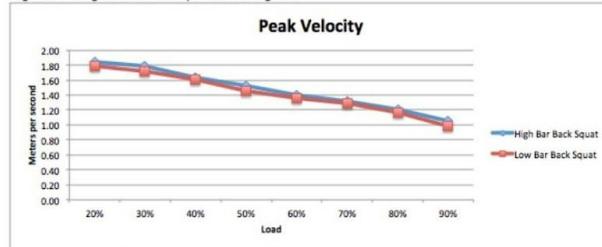


Figure 4 – Changes in Impulse with Increasing Load

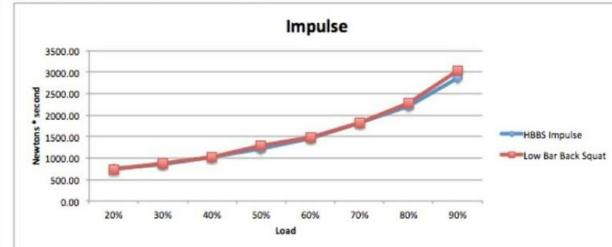


Figure 5 – Changes in Work with Increasing Load

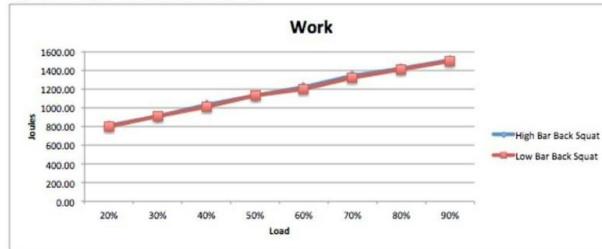
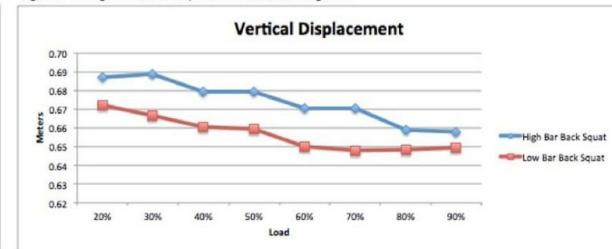
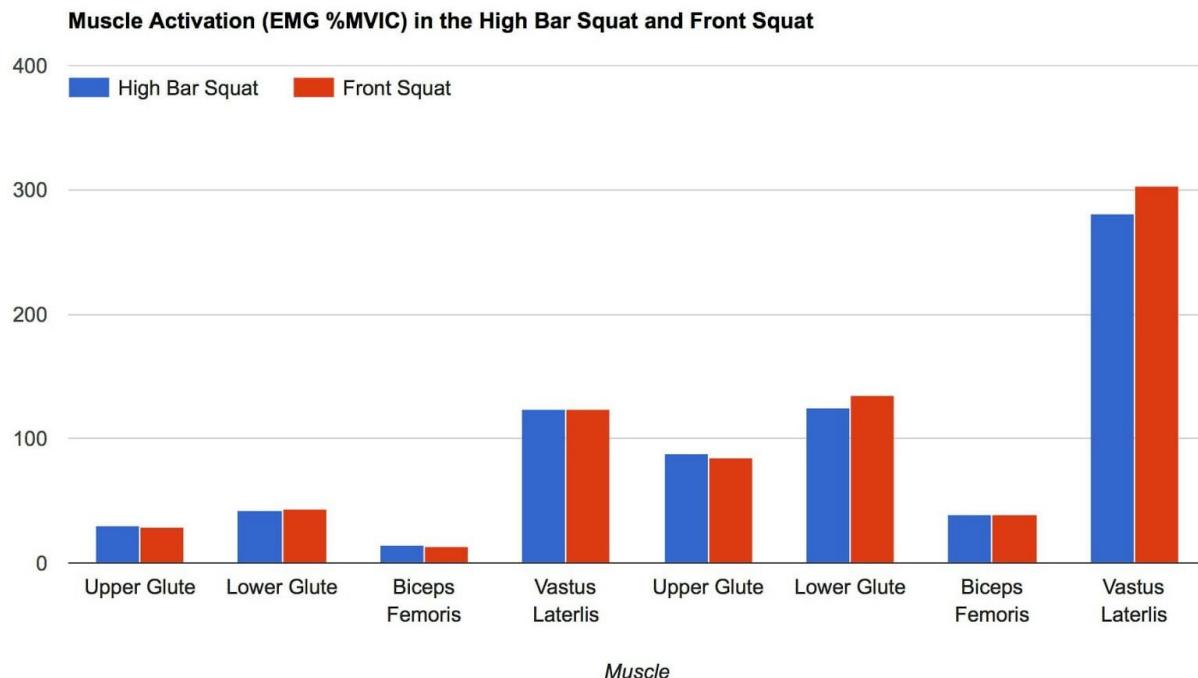


Figure 6 – Changes in Vertical Displacement with Increasing Load



Not a heck of a lot of difference here.

[This study by Bret Contreras](#) compared muscle activation in the high bar squat and the front squat (mean activation is on the left side of this graph, and peak activation is on the right):



Again, not a heck of a lot of difference.

At least when looking at acute data, it certainly doesn't seem like training effects would be meaningfully different. However, there hasn't been a longitudinal study comparing the effects of high bar squats vs. low bar squats, or front squats vs. either back squat.

It's also worth pointing out that differences in bar position don't tell the whole story, *especially* when comparing the high bar squat and the low bar squat. You can still "sit back" into a high bar squat (as many equipped powerlifters do) and you can still try to stay as upright as possible and sit down into a low bar squat (as Chad Wesley Smith does, among others).

However, there are a few things we can probably surmise:

The overall difference in whole-body training effects between all three varieties of squats is probably pretty small.

Low bar squats are probably a little better for training the hip extensors, since the hips generally go through the same ROM or a longer ROM when squatting low bar than when

squatting high bar, and they almost certainly go through a longer ROM than when front squatting. On top of a longer ROM at the hips, you can generally load them the heaviest.

High bar squats are probably a little better for training the quads since the knees go through a longer ROM when high bar squatting than when low bar squatting, and they go through a similar ROM as when front squatting. Since they're less likely to be limited by upper back strength than the front squat, you can load them heavier to train your quads a little harder.

Front squats are, hands down, the best squat variation for building upper back strength.

All three have their advantages and disadvantages. If you thought I was going to proclaim that one was better than the rest, I hate to disappoint you. I think they're all equally good at building head-to-toe strength and mass, just with slightly different emphases.

In a general sense, the best bar position for you is the one that lets you train the hardest and the most consistently. Powerlifters should at least give low bar a shot since most people can lift more weight low bar. Weightlifters should probably focus on the front squat and high bar squat, since they'll have the best carryover to the clean and snatch. For everyone else, it's primarily a matter of personal preference.

Equipment

Belts: Get one. Use it. Don't get too far out of practice squatting beltless, since it's a good skill to maintain. [MUCH more on belts here.](#)

Knee wraps: They help you squat more by increasing your maximum knee extensor moment. When your knee bends, they resist flexion, storing elastic energy to help your knees extend coming out of the hole. There's [some research](#) suggesting that they may decrease quad activation and increase the activation of your hip extensors. Getting the most out of your wraps depends on two things: practice and pain tolerance. Once you

get proficient with wraps, it's not uncommon for them to increase your squat by 10% or more.

Knee sleeves: I've never actually worn a pair of knee sleeves. I can't see how they'd help all that much, but some people swear by them. They're at least worth trying, I suppose, if you plan on competing in a federation that doesn't allow the use of knee wraps. For the love of all things holy, wash them regularly. If you don't, everyone else in the gym will hate you. Your knee sleeves always smell way worse than you think they do.

Wrist wraps: If you get wrist pain squatting and technique adjustments don't remedy the situation, they're a good investment.

Shoes: Make sure the sole is solid. Mushy soles can throw you off balance, which isn't preferable when you have a ton of weight on your back. Whether you squat with a raised heel or not is a matter of personal preference. Squatting with a raised heel versus a flat sole doesn't fundamentally change the movement in a general sense, but a lot of people strongly prefer squatting with one or the other. Get some Chuck Taylors or wrestling shoes to see how a flat sole feels, and get some cheap weightlifting shoes to see how you like a raised heel. I'd recommend not pulling the trigger on expensive flat shoes like Mark Bell's "Power Shoe" or expensive weightlifting shoes like Adipowers or Romaleos until you know which type of shoe you prefer.

Specialty bars, bands, and chains: These are all fun toys to have. For people with shoulder issues and for people who don't have enough mobility to front squat with a barbell, the [safety squat bar](#) in particular can be a lifesaver. Bands and chains may help you gain a little more strength, a little faster, based on a [recent meta-analysis](#). However, they certainly aren't necessary. If you use bands or chains as a raw lifter, I'd recommend not adding more than 20% of your 1rm to the bar in chain weight or band tension; if you go overboard, specificity starts decreasing and the overload can beat up your joints (especially with bands).

Bullet Points

Things that are entirely up to you:

1. bar position
2. hand position
3. elbow position (for back squats)
4. head position
5. stance width
6. foot angle
7. sitting back vs. sitting down
8. degree of forward knee travel etc.
9. footwear (as long as it has a solid sole)
10. squatting with a belt or not

Things that are non-negotiable:

1. Don't let your knees cave excessively.
2. Don't let your spine round.

General recommendations

1. Squat as deep as you can for general training purposes and for weightlifting.
2. Try widening your squat, sitting back, and using the low bar position to limit depth for powerlifting.
3. Try to drive your hips forward under the bar to break through the sticking point.

4. Squat low bar to build more hip strength.
5. Squat high bar to build more quad strength.
6. Front squat to build more upper back strength.
7. Lift every rep as explosively as possible

My personal squat assessment checklist for clients:

The setup:

1. Is your walkout efficient? 2-3 steps is preferable, but 4 is acceptable just to make sure everything is squared away
2. Does the middle of the bar line up with the middle of your back, or is it offset?
3. Is the bar resting firmly on your back, or is it sliding?
4. Are you breathing into your abdomen, or are your shoulders elevating when you inhale?
5. Are your wrists cocked back, or are they straight? If they're cocked back, don't worry unless it's accompanied by pain.

The lift itself:

1. Are your feet stable, or do they move? (It's not uncommon for people to start with their feet pointed too far forward, and for them to rotate out a bit during the initial descent; if the bottom of your shoes are too grippy for this to happen, then you may see the lateral part of the heel of your shoe raise a bit.)
2. Is your weight shifting excessively forward or backward? Do your heels rise off the ground, or could you lift your toes up off the ground if you wanted to?
3. Does your spine flex at any point in the movement? (Lumbar is more common than thoracic; also note whether lumbar flexion actually occurs at the bottom of

the squat, or whether your spine starts in hyperextension, and then just moves back toward neutral.)

4. Is your depth adequate for your training goals? In general, if you can maintain spinal position, deeper is better, but around parallel is generally fine for athletes and casual lifters, powerlifters should break parallel, and weightlifters should be as close to ass-to-grass as possible.
5. Is your knee tracking pretty decent? Don't worry too much about a little knee valgus or knee varus as long as there's no accompanying pain, but excessive valgus and varus should be avoided (this is a bit of a judgement call; after you see a lot of squats, you learn the difference between "your knees ticked in a bit on the ascent" and "holy shit, no, don't do that").
6. Are forces pretty evenly distributed between the quads and the hip extensors? This is usually an issue that either responds very quickly to good cuing (people with strong quads who were always taught they need to sit way back in the squat, or people with strong hip extensors who are afraid of a reasonable degree of forward lean – just getting rid of some bad habits), or it's an issue that's just indicative of your current strengths and weaknesses, with your current technique simply representing the most efficient way your body has found to move the load. If it's the latter condition, cuing doesn't affect technique or performance much, but your technique will naturally shift as you address weak links.
 1. Improve quad strength if your squats wind up looking like good mornings.
 2. Improve core bracing if there's more than a 15-20% gap between your squat and your deadlift.
 3. Improve hip extensor strength if you don't meet the first two criteria.

General Issues:

1. Do you *feel* strong, stable, and balanced under the load?
2. Does squatting cause any aches and pains, whether acute or chronic (wrist, elbows, knees, hips, back, etc.)?
3. Do you have adequate ankle, knee, and hip mobility without load? Do those things change with load? If ROM decreases when loaded, it's a control issue, not a mobility issue.
4. Do you shift your weight to one side, or do you rotate excessively? Again, this is a bit of a judgement call, since everyone is asymmetrical to some degree.
5. Are you wearing the right shoes? Any shoe with good traction and a solid sole is fine; with or without a raised heel is just a matter of preference, but cushion-y soles should be avoided.

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